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Control of Lawn Weeds and the Renovation of Lawns

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CONTROL OF LAWN WEEDS AND THE RENOVATION OF LAWNS

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INTRODUCTION

Some lawns are so polluted with weeds that renovation is advised, but in others, it is possible to remove the weeds without destroying the turf. Bulletin 613 of the Ohio Agricultural Experiment Station discusses the building and maintenance of lawns. This bulletin deals with the control of weeds in lawns.

In this bulletin are presented the results of work extending through 12 years, 1928-1940. During this period, 26 species of weeds have been studied. The work was aimed chiefly at the elimination of weeds with chemicals, but some measures were also taken to destroy weed seeds.

The term weed is used in its broad meaning—"a plant out of place."

WHERE THERE IS NOT ENOUGH GRASS TO TRY TO SAVE

In extreme cases (where the stand of desirable grasses is 25 per cent or less of the lawn area) the best way to renovate a poor lawn is to tear it up and start over, because ordinarily, the chief cause of the unsatisfactory condition is an impoverished soil. When the poor ground is plowed or spaded, commercial fertilizer can be worked in, and animal or green manures can be incorporated. A liberal supply of vegetable material is essential for the successful growth of grass. Well-rotted stable manure applied at the rate of 1 to 1½ tons or 2 to 3 cubic yards per 1,000 square feet and mixed to a depth of 4 or 5 inches is very beneficial. Peat, muck, or other similar products can be substituted for manure if it is not available. If the area is so large that the cost of such materials is prohibitive, and the element of time is not important, the desired soil condition can be obtained by growing and plowing under some crop like soybeans, buckwheat, rye, or sweet clover. Which crop is sown will depend upon the time of year the work is started and the length of time that can be allotted for the building up of the soil.

If the weeds consist principally of a dense stand of dandelions, the area can be renovated successfully without tearing up by spraying with sodium chlorate[1] and reseeding. In tests at the Ohio Agricultural Experiment Station, vigorous dandelions were killed with one treatment of a strong (18 to 24 per cent) solution of sodium chlorate[2] applied at the rate of 10 gallons per 1,000 square feet.

[1]Sodium chlorate is a very effective weed killer and, if properly handled, is entirely safe. Unless certain precautions are observed, however, it may become a grave fire hazard. The pure salt will not burn, but if it becomes mixed with combustible material, it may take fire even through friction. The following precautions must be observed:

In making the solution, avoid working on anything into which the solution might penetrate, like a wooden floor. Work on the ground or a cement surface.

In applying the solution, wear garments that can be washed, old ones that can be discarded, or a rubber coat and rubber boots, apparel from which the solution can be washed easily.

Place any remaining residue in a covered, preferably metal, container. For small quantities, a Mason jar is satisfactory. Avoid storing in anything like an open paper sack in which dirt and dust might collect.

[2]A 1 per cent solution is approximately 1⅓ ounces, or 40 grams, per gallon of water. A 12 per cent solution is approximately 1 pound, or 453.6 grams, per gallon of water.

This solution was applied with a pressure sprayer, the best means of applying all weed-killing solutions. In this strength, the chlorate killed not only the dandelions but all other lawn weeds and grasses as well. When the applications were made before January 1, they did not interfere with fertilizing and reseeding early the following spring, usually in March. On soils heavier than the Wooster silt loam, more time might be required for the leaching out of the chlorate, and the reseeding might be correspondingly delayed.

Where ground does not honeycomb readily, the seed should be covered lightly by broadcasting over it good garden loam, peat, or other similar material. An area badly infested with thrifty dandelions and thus renovated is shown in figure 1. The success of this procedure was probably due in a measure to improvement in the physical condition of the soil. The passages left in the soil through the decomposition of the large fleshy dandelion roots tend to improve both the aeration and drainage.

Fig. 1.—Renovation of ground badly infested with dandelions without spading or plowing

Sprayed November 19, 1930, with sodium chlorate in (left to right) 8, 12, 16, 20, and 24 per cent solutions. Reseeded March 17, 1931. Photographed May 9, 1932. The two stronger solutions killed practically all the dandelions.

To determine the quantity of organic matter that might be left as a residue in the soil after dandelion plants were killed, samples of roots were taken in 4-inch horizons to a total depth of 12 inches on three areas, each 1 yard square, carrying heavy stands of dandelions but little grass. After the roots were carefully washed free of soil, they were dried and ashed at low red heat in accordance with the method suggested by McCall (8). As an average of the three areas, the quantity of organic matter, calculated and expressed in terms of pounds per 1,000 square feet, was 22.3, 7.8, and 2.5 pounds in horizons 1 to 4, 5 to 8, and 9 to 12 inches, respectively, or a total to a depth of 12 inches of 32.6 pounds. This quantity of organic matter is not highly important, for, in terms of peat, it is equivalent only to a layer approximately one twenty-fifth inch thick. This amount does not represent the total organic matter, of course, because the roots may penetrate the soil to a depth of several feet; the distance varies with the type and age of the roots and the texture of the soil. In the Wooster silt loam it is not uncommon for the roots to extend to a depth of 2 or 3 feet. The deepest thus far excavated by the authors penetrated 4½ feet. The more shallow root systems are usually much branched.

Aside from organic matter, dandelion roots contain considerable nitrogen. In the three square-yard samples tested for organic matter, the average quantity of dry matter in the horizons 1 to 4, 5 to 8, and 9 to 12 inches was 23.8, 8.3, and 2.7 pounds per 1,000 square feet, respectively. Analysis of three samples of dandelion roots averaged 1.75 per cent nitrogen, approximately three-fourths of the amount usually found in the roots of alfalfa (13). The nitrogen contained in the first, second, and third horizons, therefore, was 0.42, 0.15, and 0.05 pound, respectively. In terms of ammonium sulfate, the total of these amounts is equivalent to an application of 3 pounds per 1,000 square feet; the quantity contained in the top layer alone, to one of 2 pounds per 1,000 square feet.

It is not the intention of the authors to encourage tolerance of dandelions. Mentioning these properties of dandelion roots merely indicates an explanation of the satisfactory results obtained through spraying and reseeding without tearing up the ground.

WHERE THERE IS ENOUGH GRASS TO TRY TO SAVE

Where there is enough grass to save, it is not always necessary to plow or spade up the ground or even to reseed extensively. Many weeds can be eliminated without serious permanent injury to the desirable grasses. Almost any treatment, however, will discolor the grass temporarily and may injure it some.

Experience has shown that many, though not all, weeds can be eliminated in the late fall or winter. In fact, some weeds, like mouse-ear chickweed, are more easily located in winter than in summer because their leaves remain bright green throughout the cold period. Wherever possible, treatment in that season is recommended, because the unsightliness of the usual discoloration is reduced to a minimum then. The bare spots left from the killing of mat-forming weeds, like speedwell or heal-all, can be reseeded in the early spring while the ground is in a honeycombed condition. Treated areas should be fertilized with some high-grade mixture like a 4-12-4. If reseeding is necessary, the fertilizer should be applied a week or two before seeding or after the grass is up. By following this procedure, it is possible to eliminate weeds and re-establish grass without spoiling the appearance of the lawn during the summer season.

DANDELION (*LEONTODON TARAXACUM* L.)

Among the most common and troublesome lawn weeds is the dandelion. On account of its prevalence and the difficulties involved in removing it, methods of control are considered at some length. Readers not interested in details may turn at once to the recommendations on page 9 and the summary on page 24.

CHARACTERISTICS

Dandelion is a perennial that reproduces by seed and vegetatively. A new plant may start from a fragment of root at any depth if the fragment contains enough organic food. The dandelion is so common and so universally distributed that a description for identification is unnecessary.

CONTROL

DENSE POPULATIONS

Fertilizers

AMMONIUM SULFATE

In a test started May 26, 1928, an area of Kentucky bluegrass badly infested with dandelions was treated with ammonium sulfate at five different rates, 4, 8, 12, 16, and 20 pounds per 1,000 square feet. The material was applied as a dust in the middle of sunshiny days at monthly intervals for 5 months, May, June, July, August, and September. In the first series no water was added; in the second, the plots were sprinkled before treatment; in the third, they were sprinkled after treatment. The grass was long, 4 or 5 inches, at the time of the applications.

At the close of the season the top-dressings made after sprinkling appeared to have been somewhat more effective than those made either before sprinkling or with no sprinkling at all. Most of the dandelions were eliminated without serious injury to the grass; in one season with the 12-pound, in three seasons with the 8-pound, and in five seasons with the 4-pound rate. With the 16- and 20-pound rates most of the grass was killed by the end of the third season.

In order to determine whether ammonium sulfate could be used successfully where the grass was cut more closely and in order to ascertain whether it was necessary to continue applications throughout the summer, tests were conducted during the years 1929 to 1932 inclusive. In these trials, the height of cutting and the number of treatments varied. In each of these annual tests, a series of five plots was top-dressed with ammonium sulfate at the rate of 12 pounds per 1,000 square feet. The first treatment each year was made in May. At each successive monthly application the number of plots treated was diminished by one. At the end of the season, therefore, the series as a whole, plots 1, 2, 3, 4, and 5, showed the effect of one, two, three, four, and five applications. Throughout each season, one-half of each plot in the series was mowed at a height of 1 inch; the other, at a height of 3 inches.

In each of these tests there was some burning of the grass and usually some killing in spots, more in the low-than in the high-cut grass. The tests demonstrated clearly the necessity for continuing the treatments throughout the season. On plots where the applications were discontinued after one, two, or even three top-dressings, the dandelions grew more luxuriantly than before treatment. Apparently it is necessary to keep the plants in a condition of complete or nearly complete defoliation throughout the season to destroy them.

In an attempt to avoid killing the grass, the procedure found most effective in preceding years, five monthly applications, was supplemented in 1933 with a modified plan. In the modification, the same total quantity of sulfate was used, but the quantity per application was reduced by one-half (from 12 to 6 pounds per 1,000 square feet). Applications began the middle of May and continued twice each month, on approximately the first and fifteenth, instead of once a month. To facilitate even distribution and thus avoid burning by bunching of the material, the sulfate was mixed with 10 times its weight of sand.

On a supplemental plot, three treatments were omitted in the heat of midsummer, from July 15 to August 15 inclusive. On this plot, the treatments were continued later in the fall to take the place of the omitted ones. This test was located in a pasture grazed by both cattle and sheep. Frequent and regular mowing was, therefore, not necessary. The animals on pasture grazed the grass closely.

Before the treatments were started in May 1933, the stand of dandelions was thick. A year later, May 28, 1934, a careful examination of both plots (100 square feet each) revealed a few small bare spots on the one treated monthly without summer intermission but none on the one treated semimonthly with midsummer omissions. On the plot treated monthly, 124 dandelion plants were found; on the one treated twice a month, only 2. The control was 88 and 99 per cent, respectively. The contrast between the plots treated semimonthly and the adjoining untreated areas was marked, as shown in figure 2.

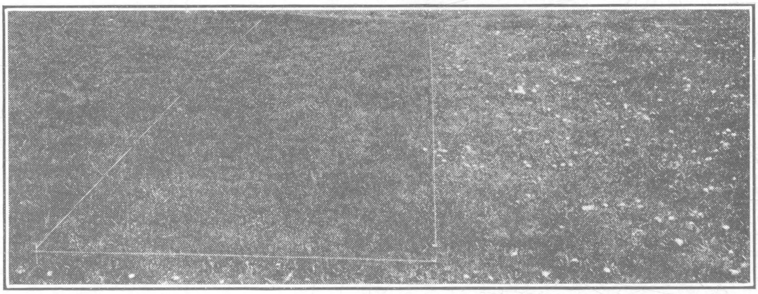


Fig. 2.—Treated with ammonium sulfate at the rate of 6 pounds per 1,000 square feet May 18, June 1, June 17, July 1, July 15, September 15, September 30, and October 14, 1933 (left); untreated plot (right)

Photographed May 9, 1934

The modified procedure including the midsummer omissions was continued in 1934 and 1935. In these years the height of grass was governed by mowing. The mowings were made midway between the treatments and at a height of 1½ to 2 inches. In 1934, the dandelion infestation of the area before treatment was dense. After treatment, in the spring of 1935, only a few dandelion plants remained. The grass was thrifty, and there were no bare spots.

FERTILIZERS OTHER THAN AMMONIUM SULFATE

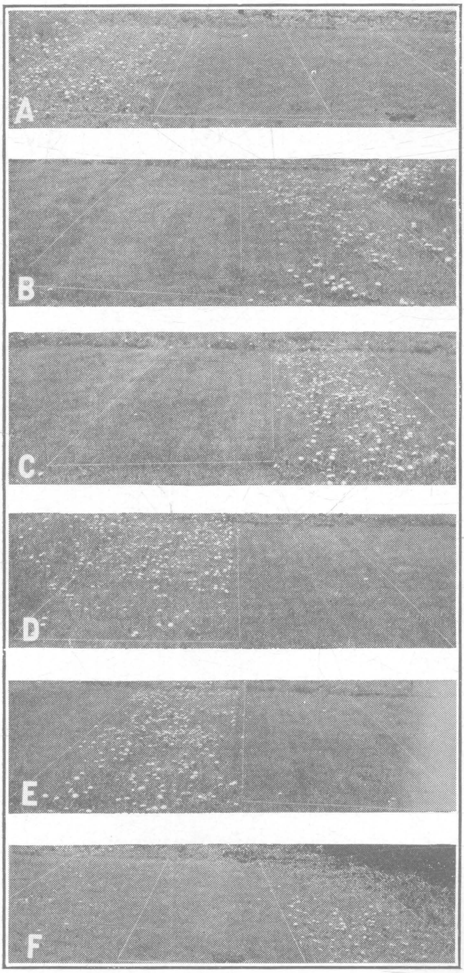
In the later years of these tests, fertilizers other than ammonium sulfate were included. In 1935 the additional ones used were Ammo-Phos A[3] (ammonium phosphate), Nitrophoska,[4] a homemade 10-6-4,[5] Cyanamid, and sodium nitrate. The applications of each were made at the same time as those of ammonium sulfate, May 17, June 1, June 22, July 1, July 15, August 3, August 20, August 31, September 16, and October 2. Applications were made to supply a quantity of nitrogen equivalent to that carried by the ammonium sulfate. All applications were made on areas heavily infested with dandelions.

[3]Ammo-Phos A is manufactured by the American Cyanamid Co., 535 Fifth Ave., New York City.

[4]Nitrophoska is manufactured by the Synthetic Nitrogen Products Corp., 285 Madison Ave., New York City.

[5]Made from ammonium sulfate, 20 per cent superphosphate, and muriate of potash.

The following season, in the spring of 1936, the stand of dandelions was reduced markedly by all treatments, as shown in figure 3. Little, if any, difference in effectiveness was found between these materials or between any of them and ammonium sulfate. The use of Cyanamid resulted in considerable burning, much more in 1934 than in 1935. The seemingly disastrous results obtained in 1934 were not permanent, for the grass eventually re-established itself. Experiments showed that the effectiveness of some materials, such as Nitrophoska, was increased by pulverizing the coarser pebble-like particles.



A—Ammonium sulfate, 6 pounds per 1,000 square feet per application
Three midsummer treatments omitted on plot in middle and applications not continued into the fall. Spot in foreground (right) due to removal of sod

B—Ammo-Phos A, 11.25 pounds per 1,000 square feet per application

C—Nitrophoska, 8 pounds per 1,000 square feet per application

D—10-6-4, 12 pounds per 1,000 square feet per application

E—Cyanamid, 5.75 pounds per 1,000 square feet per application
Three midsummer treatments omitted on plot next to check

F—Sodium nitrate, 8 pounds per 1,000 square feet per application
Spot in foreground (left) due to removal of sod

Fig. 3.—Dandelions treated with various fertilizers in 1935

Photographed May 9, 1936

RECOMMENDATIONS

As a result of 8 years of work with ammonium sulfate as an agent for the control of dandelions, it is recommended that this material be applied at the rate of 6 pounds per 1,000 square feet, that applications be begun as soon as the dandelions come into bloom or a little before (about May 1), and that they be continued at semimonthly intervals for 4 or 5 months, or until the leaves cease to reappear. Usually 8 to 10 top-dressings are required. To facilitate even distribution and avoid, as far as possible, temporary injury and unsightliness from burning, the sulfate should be mixed with 8 to 10 times its weight of sand. For best results it should be applied in clear weather in the morning when the leaves are wet with dew. In extremely hot, dry weather in midsummer, two or three treatments may well be omitted, but if they are, the series of treatments will need to be continued later than otherwise in the fall. Mowings should be made as high as possible, 1½ or 2 inches, and a few days after treatment. Even though long grass intermixed with coarse leaves like those of dandelions is unsightly, this condition will have to be tolerated during the season of eradication, for short grass is more susceptible than long grass to permanent injury from burning.

Other fertilizing materials, such as Ammo-Phos A, Nitrophoska, and sodium nitrate, used in quantities that carry an equivalent of nitrogen, can be substituted for ammonium sulfate.

WHY FERTILIZERS KILL DANDELIONS

Formerly, it was thought that ammonium sulfate controlled dandelions by creating an acid soil condition (3) in which dandelions could not live. It is true that ammonium sulfate in the quantity used in these tests (60 pounds per 1,000 square feet per season) made an appreciable change in the reaction of the soil, at least in the upper strata. Table 1 gives the reaction in 1-inch horizons for the upper 4 inches on the check and sulfated plots in the dandelion tests for 1931, 1932, 1933, and 1934. The soil samples were collected and tested in November 1934. The results, therefore, show the effect on the soil reaction of the sulfate 3 years after application (1931), 2 years after (1932), 1 year after (1933), and the year of application (1934).

TABLE 1.—Effect of ammonium sulfate on reaction of soil
(Soil reaction expressed as pH)

Horizon	1931		1932		1933		1934		Average	
	Ammonium sulfate	Check	Ammonium sulfate	Check	Ammonium sulfate	Check	Ammonium sulfate	Check	Ammonium sulfate	Check
First inch	5.45	7.00	4.75	6.10	5.55	6.67	6.50	7.85	5.56	6.91
Second inch	5.48	7.15	4.75	6.15	5.70	6.45	6.90	7.65	5.71	6.85
Third inch	5.55	7.28	4.85	6.15	6.07	6.85	7.25	7.70	5.93	6.99
Fourth inch	6.00	7.30	4.95	6.00	6.40	7.30	7.20	7.60	6.14	7.05

It is true also that dandelions are sensitive to high acidity. In a reaction weed test in which the degrees of acidity represented were pH 4, 4.5, 5, 5.5, 6, 7, and 8, the vigor of dandelions decreased as the acidity increased, and on the most highly acid soil dandelions failed altogether.

Another illustration of the effect of mild acidity on the growth of dandelions was obtained on the "watering plots."[6] The bent section of these plots, after having been destroyed by sod webworms in the summer of 1931, was plowed up December 16 of that year. To the south half of each of these plots, enough aluminum sulfate was applied to change, theoretically, the reaction of the soil to a depth of 6⅔ inches from pH 6.8 to pH 5.5. To facilitate thorough mixture with the soil, one-half of the sulfate was applied before, and one-half after, plowing. In the spring a good seedbed was prepared, and on April 21, 1932, stolons of the Washington strain of creeping bent were planted. A good stand was secured.

At the close of the third season, in October 1934, the average reaction on the untreated and treated areas was pH 7.14 and pH 6.24, respectively. At that time the number of dandelions on the treated area was much smaller than on the untreated, table 2. The number, total weight, and average weight of dandelions on the treated area were approximately 60, 45, and 69 per cent, respectively, of those on the untreated. In table 2 is shown also the comparative growth on the untreated and treated areas of broad-leaved plantain and Kentucky bluegrass (practically all the bent had been superseded by Kentucky bluegrass). The reaction of the soil had little, if any, effect on the growth of broad-leaved plantain. On the treated area the growth of Kentucky bluegrass was approximately 42 per cent of that on the untreated. Several patches of sorrel had developed on the treated area.

It is difficult to account for the disappearance of the dandelions by the reaction of the soil. Although the plots treated with ammonium sulfate in 1931 and 1932 had become very acid by 1934 (table 1), it is probable that at the close of the season of treatment they were no more acid than was the one treated in 1934. Certainly a pH of 6.5 (1934) at the surface, and higher below, would not kill dandelions, plants with roots penetrating the soil to a depth of 4 or more feet. Soil samples taken promiscuously in areas badly infested with dandelions often show a higher degree of acidity than that represented by pH 6.5. As already shown, moreover, in 1933, 1934, and 1935, dandelions were killed by the use of materials other than ammonium sulfate, fertilizers, such as Nitrophoska, which has little or no effect on the reaction of the soil, and even Cyanamid and sodium nitrate, both of which result not in acidity but in alkalinity.

Fertilizers exhaust dandelions. The immediate effect of an application of ammonium sulfate or any of the other fertilizers mentioned is to burn off the leaves. The ultimate effect of periodic defoliations is exhaustion, as was brought out in a hand test.

That repeated defoliations alone, without the use of any fertilizer, would kill dandelions if continued throughout the season, was shown by the results of a test conducted in the summer of 1934. In that year, 50 large, thrifty dandelion plants were labeled and defoliated at the ground level with shears on the following dates: May 18, June 25, July 23, August 25, September 20, October 16, and November 18. The average green weight of leaves per plant and the number of plants surviving from month to month are shown graphically in figure 4.

[6]A series of plots formerly used in a test in artificial watering.

TABLE 2.—Effect of aluminum sulfate and resulting reaction of soil on number and size of dandelions, number and size of broad-leaved plantain, and growth of Kentucky bluegrass

(Plots 6 by 12 feet)

Plant	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6		Plot 7		Average	
	pH 6.82	pH 5.80	pH 7.20	pH 5.72	pH 7.10	pH 6.70	pH 7.32	pH 6.50	pH 7.25	pH 6.58	pH 7.00	pH 5.70	pH 7.30	pH 6.65	pH 7.14	pH 6.24
Dandelion																
Number	26	5	54	30	33	30	28	14	22	16	30	20	52	31	35	20.9
Total green weight (grams)	280	32	732	156	581	560	585	110	219	174	391	123	561	351	478	215.1
Average green weight (grams)	10.8	6.4	13.6	5.2	17.6	18.7	20.9	7.8	10.0	10.9	13.0	6.2	10.8	11.3	13.8	9.5
Broad-leaved plantain																
Number	13	3	8	8	2	7	3	8	5	1	7	4	6	6	6.3	5.3
Total green weight (grams)	260	16	216	108	49	140	46	99	78	11	145	101	101	237	128	102
Average green weight (grams)	20	5.3	27	13.5	24.5	20	15.3	12.4	15.6	11	20.7	25.2	16.8	39.5	20	18.1
Kentucky bluegrass																
Total green weight (grams)	2,690	861	2,320	681	1,575	871	1,315	511	1,090	596	1,480	776	1,905	806	1,768	729

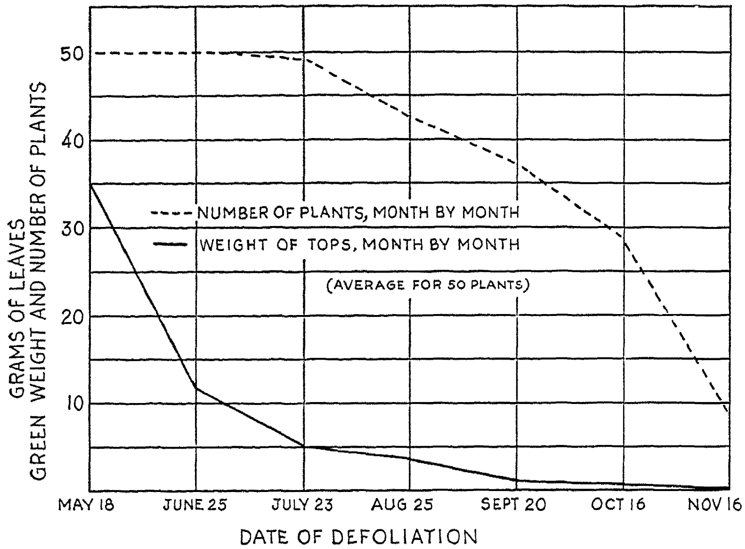


Fig. 4.—Effect of repeated defoliations on the growth and survival of dandelions

No loss in number of plants occurred until the third defoliation, July 23, but after that, the number of casualties increased rapidly; nine only, or 18 per cent of the total, survived at the last defoliation, November 16. The area was re-examined June 6, 1935. Of the original 50 plants, 8, or only 6 per cent, had sent out leaves. All these were spindling and weak.

That gradual exhaustion of dry matter and finally death result from repeated and close defoliations was shown by the results obtained in an experiment conducted in 1934. In this test in an ungrazed pasture, three adjoining areas, each 10 by 10 feet, all badly infested with rank, thrifty dandelions, were handled as follows: On one area, the dandelions were uncut (check). On the second, dandelions were defoliated in May, June, July, August, and September by treating with ammonium sulfate at the rate of 12 pounds per 1,000 square feet. On the third plot, dandelions were defoliated on the same dates by cutting with shears at the ground level. At each time of defoliation, root samples to a depth of about 7 inches were gathered, and on these, the percentage of dry matter was determined. The results were as shown in table 3.

TABLE 3.—Dry matter content of the roots of dandelions as affected by repeated defoliations in 1934

Date	Check	Defoliated with ammonium sulfate	Defoliated with shears
	Per cent	*Per cent*	*Per cent*
May 29	19.2	20.4	22.1
June 27	22.6	18.7	20.8
July 25	23.6	16.0	15.2
August 31	25.8	14.7	13.6
September 30	26.8	14.1	10.9
October 29	27.4	14.5	14.4

From table 3 it can be noted that on the check plot, the percentage of dry matter in the roots of the dandelions increased progressively throughout the summer. On the other two plots, where the dandelions were repeatedly defoliated, the reverse was true except for the last month, October, when the percentage rose somewhat.

At the time of the last sampling, in October, there was a marked contrast in number of plants between the untreated and treated plots. On the check, there had been no appreciable loss in plants aside from the few removed in sampling. On each of the defoliated plots, only a few plants remained. The following spring, May 13, 1935, when dandelions in general were in bloom and well advanced, an examination revealed 125, 2, and 5 dandelion plants on the plots untreated, defoliated with ammonium sulfate, and defoliated with shears.

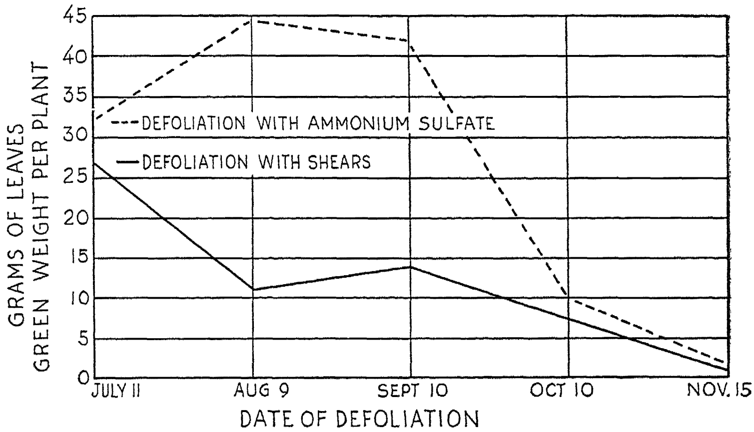


Fig. 5.—Ammonium sulfate accelerated the rate of growth of leaves.

Defoliation by hand is, of course, impracticable. Moreover, the process of exhaustion is hastened through the use of a fertilizer like ammonium sulfate that not only burns off the leaves but at the same time stimulates growth. In a poultry pasture, dandelions on each of five plots, 10 by 10 feet, were defoliated with shears at the ground level July 11, 1934. On plot 1, the check, defoliation with shears was repeated August 9, September 10, October 10, and November 15. Plots 2, 3, 4, and 5 were also dusted with ammonium sulfate at the rate of 12 pounds per 1,000 square feet. Plots 3, 4, and 5 were again dusted with ammonium sulfate on August 9; plots 4 and 5, again September 10; and plot 5, again October 10. At the close of the experiment, therefore, the plots treated with ammonium sulfate consisted of a series that had received one, two, three, and four applications of ammonium sulfate in addition to the initial defoliation with shears. At the beginning, 25 plants in each plot were labeled, and on the basis of the growth made by them, the average weight of leaves per plant between defoliations was determined. These averages for the plot repeatedly defoliated with shears, on the one hand, and for the series treated with ammonium sulfate, on the other, are shown graphically in figure 5. From this graph it is apparent that the ammonium sulfate greatly increased the growth of leaves. It also increased the percentage of nitrogen from 2.72 per cent to 3.50 per cent and, consequently, the total nitrogen in them. In the metabolic processes involved in the development of new leaves, the carbohydrates required to combine with the nitrogen would, therefore, be greater in the plants defoliated with sulfate than in those defoliated with shears. Since in the absence of fully developed leaves, the carbohydrates must come largely from the root reserves, it follows that the exhaustion of these reserves, and, hence, the death of the plants, would be hastened by the use of the sulfate. That the sulfate did accelerate the depletion of the reserves and consequent death of the plants was shown by a count of the remaining living plants.

In the following spring, May 9, 1935, each of the plots was re-examined to note the condition of the 25 plants which had been labeled. The percentage killed on the plot defoliated with shears alone was 52, on the ones defoliated once with shears and one, two, three, and four times with ammonium sulfate, it was 20, 64, 88, and 100, respectively.

In 1935, a similar test was conducted. It was started in May, however, instead of in July, and one additional defoliation was made. The results of these treatments were noted the following year, July 2, 1936. The percentage of the 25 labeled plants killed on the plot which had been defoliated six times with shears was 92; on those which had been defoliated once with shears and one, two, three, four, and five times in addition with ammonium sulfate, it was 72, 88, 96, 96, and 100, respectively.

The higher percentage of control in the second than in the first test was probably a result of starting the treatments earlier. As will be pointed out later, the food reserves in dandelion roots are lower in May than in July, and the work required to exhaust the plants is, therefore, somewhat minimized if the treatments are started at the earlier date.

OBJECTIONS TO USE OF FERTILIZERS

Too much mowing.—A fancied objection to repeated liberal applications of ammonium sulfate or any other fertilizer as an agent of defoliation is that in subsequent years such treatment will result in much additional mowing. This criticism is made even though it is usually recognized that the fundamental difficulty with a weedy lawn is an impoverished soil. In 1936, the dandelion plots treated in 1935 were mowed, and the grass was weighed throughout the season. In this test, ammonium sulfate was used as the standard, and the other materials were applied in quantities that would furnish approximately an equivalent of nitrogen. The kind and quantity of fertilizers used, the yield, and the increase or decrease of grass obtained were as shown in table 4.

From table 4 it can be seen that the growth of grass on the treated plots in the first year after top-dressing exceeded the combined growth of grass, dandelions, and white clover on the check plots. The amount of the increase ranged from 4 to 36 per cent. In the second year, however, the reverse was true, and the decrease ranged from 65 to 89 per cent. The difference in results obtained in the two seasons was due largely to a much greater growth of dandelions and white clover on the check plots in the second than in the first year. The growth of grass on all plots, with the exception of the one fertilized with Ammo-Phos A, was substantially the same in both seasons.

TABLE 4.—Effect of equivalent quantities of nitrogenous fertilizer used in 1935 on the weight of green grass produced in 1936 and 1937

(All weights of fertilizer and grass are in terms of pounds per 1,000 square feet.)

Fertilizer		Yield		Increase (+) or decrease (−)			
Kind	Quantity	1936	1937	1936	1937	1936	1937
				Pounds	*Pounds*	*Per cent*	*Per cent*
Ammo-Phos A	11.25	298	184	+106	−163	+36	−89
Cyanamid....	5.75	205	202	+ 13	−145	+ 6	−72
Nitrophoska...	8.00	236	210	+ 44	−137	+19	−65
10-6-4.........	12.00	201	208	+ 9	−139	+ 4	−67
Sodium nitrate	8.00	269	*	+ 77	....	+29	....
Ammonium sulfate......	6.00	249	*	+ 57	....	+23	....
Checks	....	192	347	....	....	....	....

*The plots treated with sodium nitrate and ammonium sulfate had to be abandoned in 1936; hence, no yields from these two plots were obtained in 1937.

Stimulation of crabgrass.—The use of fertilizer is not recommended for the control of dandelions on areas badly infested with crabgrass. Fertilizer stimulates crabgrass, a hot-weather plant, into vigorous growth. Such growth in midsummer may result in considerable injury to the desirable grasses, for at that season, they are more or less dormant and are not, therefore, able to compete favorably with crabgrass. This difficulty can be largely overcome by using a nonfertilizing agent, such as iron sulfate (copperas), in the first part of the season while crabgrass is starting and then finishing the defoliations with a suitable fertilizer. Such a procedure, followed in 1936, prevented the establishment of crabgrass. This method avoids an excessive use of fertilizer but provides enough to correct the basic difficulty, low fertility.

Other Killing Agents

Repeated treatments with fertilizer involve prolonged and sustained effort, but the writers know of no material with which dandelions can be killed with a single application without killing much or all of the grass. In an effort to find more efficient agents, other materials were tried.

ARSENIC PENTOXIDE

In 1935, arsenic pentoxide was used on a lawn in three strengths, ⅛, ¼, and ½ pound of elemental arsenic[7] per 1,000 square feet, on a duplicate set of plots 5 by 20 feet. On both sets, one spraying was made July 19; on one of the sets, a second spraying was made August 16. From observation in late October, it was apparent that the two weaker solutions had killed neither the dandelions nor the grass. One application of the strongest solution had reduced the number of dandelions slightly; two applications, considerably. Two applications had injured the grass appreciably. This test was conducted on Kentucky bluegrass that was mowed frequently.

A fall application of the same three strengths was made in duplicate on a Kentucky bluegrass lawn October 31, 1935. The results on these plots were

[7]One-eighth pound of elemental arsenic equals approximately 0.38 pound, or 174 grams, of arsenic pentoxide. One-fourth pound of elemental arsenic equals approximately 0.76 pound, or 348 grams, of arsenic pentoxide. One-half pound of elemental arsenic equals approximately 1.52 pounds, or 696 grams, of arsenic pentoxide.

unsatisfactory. The following summer, dandelions were abundant on all the plots. On the ones to which the strongest solution was applied, the grass was badly injured.

A test under field conditions, identical in time and rate of application with the one made in summer under lawn conditions, was carried out in 1935. This test was located in a poultry pasture where the grass had been mowed once in June with a mowing machine. The dandelions were strong and vigorous. The test plots were 10 by 10 feet. In this test, the location of 25 plants selected at random in each plot was marked. From the time of treatment until November 1, the aboveground condition of these plants was noted at weekly intervals.

In this same poultry pasture, two additional plots of vigorous dandelions were sprayed October 31 with the strongest solution, the ½-pound strength. In each of these plots also, 25 dandelions were labeled.

The following spring, May 25, after dandelions in general were in vigorous growth, the percentage of survival of the labeled plants in both the summer and fall tests from the ⅛-, ¼-, and ½-pound strengths was 100, 100, and 96, respectively, from one application (July 19) and 100, 88, and 56, respectively, from two applications (July 19 and August 16). In the fall test (October 31) the percentage of survival was 96 in both plots.

For all the plants that survived, the time required for the disintegration and redevelopment of the upper part of the roots, or the period from the last treatment to the first appearance of new leaves, ranged from 3 to 12 weeks. Examination showed that the strongest solution destroyed the roots to a depth of 5 or more inches.

In 1936, the ½-pound strength was applied once on a fairway, which received close mowing, once on a lawn, which had ordinary mowing, and once on an area of bluegrass mowed twice in the season with a mowing machine. The fairway plot was sprayed June 17; the other two, July 7. Each of the plots contained 100 square feet. The number of dandelions on each of these plots was counted at the time of spraying and again November 17. On the fairway plot, the number of dandelions was reduced from 758 to 374, a kill of 50.7 per cent. On the lawn plot, the number was reduced from 821 to 274, a kill of 66.6 per cent. In the meadow, where the dandelions were large, the number was reduced from 149 to 118, a kill of 20.8 per cent. On the fairway and on the lawn, the grass was severely injured; approximately 50 per cent or more was killed. The injury to the long grass in the meadow was less marked. The injury to the grass from one application in 1936 was greater than that from two applications in 1935. The 1936 applications were followed by a period of excessively hot weather, a series of days in which the thermometer registered 100° F. or more in the shade. Incidentally, these results show that small dandelions are more readily killed than large ones, for the percentage of kill in the meadow was much less than on either the lawn or the fairway.

AMMONIUM THIOCYANATE

An experiment was conducted in the winter of 1932-1933 to determine whether dandelions could be killed at that season without serious injury to the grass by the use of ammonium thiocyanate liquor.[8] The material was applied

[8]In this and subsequent tests where a thiocyanate spray was employed, the material used was the amber-colored ammonium thiocyanate liquor, the mother liquor from which the crystalline form is derived. It contained approximately 2 5 pounds of ammonium thiocyanate per gallon. The material was supplied by the Kopper's Products Company.

at the rates of 2, 4, 6, 8, and 10 gallons per 1,000 square feet. The first set of plots was sprayed November 30; the second set, December 28; the third set, January 24; and the fourth set, February 27. The plots were 5 by 20 feet. Ammonium thiocyanate was effective, but even the heaviest rate was not strong enough to kill all the dandelions. In this strength, moreover, it did injure the grass severely. As an agent for killing dandelions, therefore, at least in the winter, this material was not satisfactory. For treating individual plants (spotting), however, it is effective. If used in adequate quantities, it kills the dandelions, and the nitrogen contained in it stimulates growth and thus tends to hasten a covering of the bare spots.

IRON SULFATE

In 1919, Munn (10) reported satisfactory control of dandelions from spraying with iron sulfate (copperas). If this material comes in contact with cement walks, stone foundations, clothing, or other materials, it develops a yellowish rusty stain that is not easy to remove. It also discolors grass temporarily.

To avoid the unsightliness in midsummer, when it is most objectionable, a series of dandelion plots was treated in the winter months of 1930-1931. The results were negative. Apparently the effectiveness of this agent is due not to action on the roots but to repeated defoliations similar to those caused by ammonium sulfate.

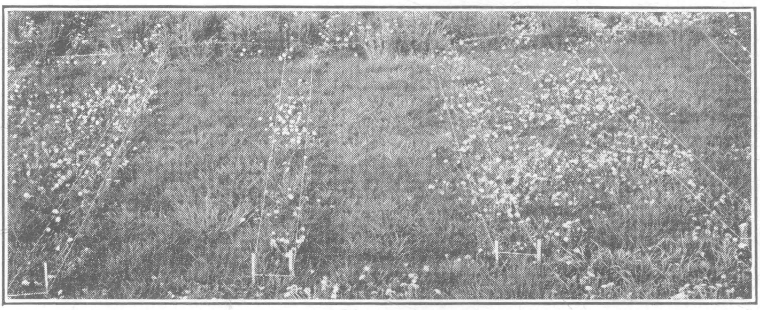


Fig. 6.—Dandelion plots treated with iron sulfate May 26, June 22, July 27, August 29, and September 28, 1931

Left—Sprayed only
Middle—Leaves first bruised by pounding with an iron rake and then sprayed
Right—untreated
Photographed May 11, 1932

In the summer of 1931, vigorous, thrifty dandelions were sprayed with iron sulfate, 1½ pounds per gallon of water. The solution was used at the rate of 3⅓ gallons per 1,000 square feet. The test plots were 5 by 20 feet. One set of triplicate plots was sprayed without other treatment. On a second set of triplicate plots, the dandelion leaves were first bruised by pounding with an iron rake and then sprayed. On both sets, the sprayings were made May 26, June 22, July 27, August 29, and September 28. A third set of triplicate plots, not treated, was included to serve as a check. The five sprayings alone resulted in an almost complete elimination of the dandelions. At no time during the year was it observed that bruising the leaves prior to spraying was essential or even advantageous. The contrast between the sprayed and unsprayed plots the following year, May 11, 1932, was marked, as illustrated by a typical set of the triplicates, shown in figure 6.

SODIUM CHLORATE

Dandelions were killed without severe permanent injury to the grass by repeated sprayings with a dilute solution of sodium chlorate. An area of Kentucky bluegrass badly infested with well-established and vigorous dandelions was sprayed in 1929 with sodium chlorate in various strengths at different frequencies. The plots were 5 by 20 feet. The chlorate was applied at the rate of 10 gallons per 1,000 square feet.

The only combination that resulted in the elimination of practically all the dandelions without permanent injury to the grass was the one-half per cent solution applied at weekly intervals from May 16 to October 10 inclusive with the exception of the first week in August, a rainy period. Weekly applications of even a 1 per cent solution killed the grass, as shown in figure 7. Neither dandelions nor grass survived either weekly or monthly applications of 4 or 6 per cent solutions of sodium chlorate.

Fig. 7.—Twenty-one weekly sprayings with a one-half per cent solution of sodium chlorate killed practically all the dandelions but not the grass (left). The same number of applications of a 1 per cent solution killed the grass (right) but did not interfere with reseeding the following spring.

Photographed May 10, 1930

Weekly applications of a one-half per cent solution of sodium chlorate are not recommended as a satisfactory method of control. The test, however, serves as a further illustration that repeated defoliations, regardless of the agent employed, result eventually in the death of dandelions.

INDIVIDUAL PLANTS

Cutting

DEPTH OF CUTTING

To determine the depth to which dandelion roots must be cut in order to kill the plants, a large number of thrifty individuals were excavated, and from six dozen of the best of these, a section of root 6 inches long was removed immediately below the crown. These sections were divided into comparable groups of a dozen each, and the groups were planted in glazed jars. Each individual root within the group was planted in a vertical position with the upper end covered to the same depth. The depths of covering in the six jars were 1, 2, 3, 4, 5, and 6 inches, respectively. The jars were kept in a greenhouse and were well watered. Eventually, leaves appeared on the roots covered 1, 2, and 3 inches, but none developed on those buried 4 or more inches.

A second experiment, conducted in a similar manner, showed that shoots developed from sections taken at a depth of 2 or 3 feet if the roots at that depth were large enough to contain an abundant supply of food reserves. Longyear (6) reported that sections of dandelion roots taken from a depth of 18 inches sent out sprouts.

The greenhouse tests suggested that hand cutting is probably a waste of time unless the dandelions are small or the cutting is deep, for food reserves in the entire root system, not just in a relatively small section, are available for new growth. To determine the depth of cutting required to kill under field conditions, groups of 25 plants each were cut off at depths below the surface of 2, 3, 4, and 5 inches. In 1934, one set was cut in the spring, May 29, and one in the fall, September 19. In 1935, the spring groups were cut off on May 27, and the fall groups, October 31. The plants, located in an experimental alfalfa field in lanes reserved for convenience in harvesting the crop, were strong and vigorous. They were mowed with a mowing machine as often as the alfalfa was cut, 3 or 4 times a year. On the plants decapitated in 1934, the results were recorded May 15 to 18, 1935; on those cut off in 1935, the records were taken June 6 to 8, 1936. In taking notes, roots from which new growth had started were regarded as alive even though the leaves had not yet reached the surface of the ground. The proportion of these was very small, for at the season the notes were taken, dandelions in general were past bloom and had been in vigorous growth for several weeks. The results obtained were as shown in table 5.

Fig. 8.—Dandelions sprouted from roots cut off at depths of 2, 3, 4, and 5 inches below the surface of the ground September 11, 1934.
Photographed May 17, 1935

TABLE 5.—Percentage of dandelions that died as a result of cutting off the roots at depths of 2, 3, 4, and 5 inches

Year	May				September-October			
	2 inches	3 inches	4 inches	5 inches	2 inches	3 inches	4 inches	5 inches
1934..........	35.0	91.7	81.8	95.7	12.0	12.0	28.0	32.0
1935..........	66.7	86.4	100.0	100.0	8.0	27.8	14.3	32.0

From table 5, it can be seen that in general, the lower the dandelion roots were cut off, the greater was the mortality. Cutting to a depth of 4 or even 5 inches, however, did not ensure death even though it did weaken the plants (fig. 8). If dandelion roots are not cut off deep enough to kill, the cutting may result in the development of not one, but of many, new shoots (fig. 9).

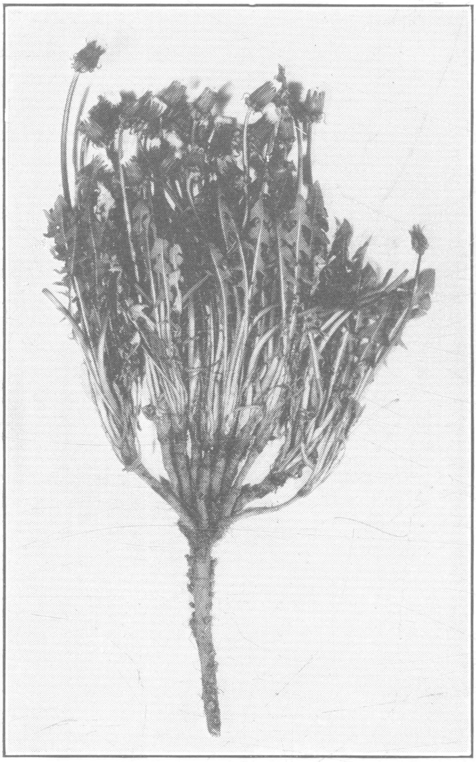


Fig. 9.—Dandelion root cut off 5 inches below the surface November 2, 1933
Photographed May 20, 1935

TIME OF CUTTING

From table 5 it can be noted also that in both years, cutting off in the spring was more effective than cutting off in the fall. Presumably, this difference was due to variation in the quantity of dry matter stored in the roots at different seasons of the year. That the content of dry matter varies through the year is shown by results obtained in 1929, 1930, 1931, and 1932. During the growing season of these 4 years, samples of dandelion roots were gathered to a depth of approximately 6 inches at weekly intervals. As far as the condition of the soil would permit, samples were gathered also at monthly intervals through three winters. On these samples, the percentage of dry matter was determined. The average of these percentages is shown graphically in figure 10.

From the graph, it appears that the dry matter in dandelion roots gradually declines in the early spring, reaching a minimum in late April or a little before blooming, then increasing, sharply at first, more gradually later. The higher percentage of dry matter and, hence, the lower percentage of moisture, in late July and August as contrasted with the fall months are probably a reflection of the lower moisture content of the soil in midsummer than in the fall.

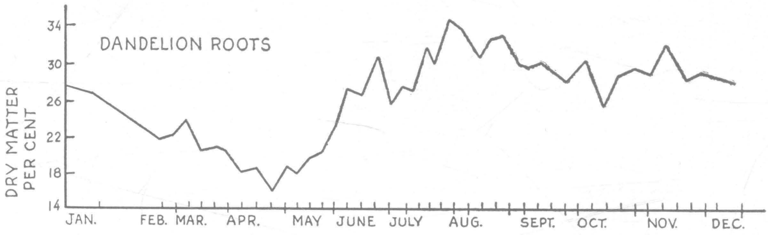


Fig. 10.—Percentage of dry matter in dandelion roots throughout the year

The gradual decline followed by a gradual increase in dry matter each season is probably due chiefly to loss of organic food reserves, particularly sugars. Samples of roots gathered January 30, April 29, and September 28, 1937, showed a marked depression for the spring period in both total sugars and in easily hydrolyzable carbohydrates. The percentage (green weight basis) of total carbohydrates was 10.5, 6.6, and 20.2 for January, April, and September, respectively.

Since the leaves of dandelions wither and die in the fall, new ones must develop in the spring. Early spring growth takes place wholly or in part at the expense of the reserves stored in the roots and, hence, there is a gradual loss of these reserves. As the leaves develop and increase in size, a time is reached eventually when the products manufactured by the leaves equal and finally exceed the requirements for growth. As soon as this stage is reached, storage begins.

TABLE 6.—Relative value of various materials for killing individual dandelions

Material	Quantity used	1935 Plants			1936 Plants		
		Alive	Dead	Doubtful	Alive	Dead	Doubtful
Ammonium thiocyanate crystals	1 teaspoonful*	....	....	....	13	9	3
Ammonium thiocyanate liquor	15 cubic centimeters	....	.. ...	....	7	14	4
Ammonium thiocyanate liquor	25 cubic centimeters	0	22	3	3	18	4
Nitrophoska	2 teaspoonfuls	24	1	0	....	....	....
Nitrophoska	4 teaspoonfuls	13	0	12	....	....	....
Sodium chloride (common salt)	4 teaspoonfuls	16	9	0	....	....	....
Ammonium sulfate	2 teaspoonfuls	19	4	2	....	....	....
Ammonium sulfate	4 teaspoonfuls	11	10	4	18	7	0
Arsenic pentoxide	2 cubic centimeters	....	....	....	11	14	0
Arsenic pentoxide	3 cubic centimeters	....	....	....	6	18	1
Benzol	10 cubic centimeters	....	....	....	0	23	2
Benzol	15 cubic centimeters	0	23	2	....	....	....
Furfural	5 cubic centimeters	13	10	2	4	15	6
Furfural	10 cubic centimeters	....	....	....	1	20	4
Gasoline	15 cubic centimeters	16	4	5	4	17	4
Gasoline	20 cubic centimeters	....	....	....	5	20	0
Gasoline	25 cubic centimeters	....	....	....	0	23	2
Kerosene	5 cubic centimeters	14	8	3	....	....	....
Kerosene	15 cubic centimeters	....	....	....	0	23	2
Kerosene	25 cubic centimeters	....	....	....	0	25	0
Petrol ether	15 cubic centimeters	24	1	0	....	....	....
Sodium chlorate, 50 per cent solution	3 cubic centimeters	6	10	9	12	13	0
Sodium chlorate, 75 per cent solution	2 cubic centimeters	....	....	....	0	23	2
Sodium chlorate, 75 per cent solution	3 cubic centimeters	....	....	....	0	25	0

*One teaspoonful equals approximately 7.5 cubic centimeters.

Presumably, dandelions are weakest when their food reserves are lowest. Since this condition occurs about the time of, or shortly before, the first appearance of bloom, it follows that then is the most effective time to attack them. In the latitude of Wooster, Ohio, blooming usually starts in late April or early May.

Spotting with Chemicals

Because of the depth of root destruction required to kill, and because of the branching habit of growth of many roots, it is obvious that cutting or spudding is impractical as a method of control for dandelions. Spotting with some chemical agent is a more feasible procedure for killing individual plants. For comparison of various agents, strong, vigorous dandelions in groups of 25 each located in a general field were labeled and treated September 11, 1934. Other groups of the same class of plants were treated November 12, 1935. A record of the effect of the 1934 treatments was made May 29, 1935; of the 1935 treatments, May 26, 1936. In making the records, plants were classed as alive, dead, or doubtful. If leaves were present, the plant was regarded as living. If no remnant of the root could be found, or if the remnant showed no signs of sending out leaves, the plant was rated as dead. If the stub root was sending out leaves but they had not yet reached the surface of the ground, the plant was classed as doubtful. The kind and quantity of material used and the results obtained were as shown in table 6.

Fig. 11.—Dandelions treated with 15 cubic centimeters of kerosene September 11, 1934. Roots were destroyed to a depth of 2 to 4 inches, but new growth developed on the stubs of most of them. Photographed May 17, 1935

From table 6 it can be seen that fairly satisfactory results were obtained from the use of 10 cubic centimeters of benzol and furfural, from 15 to 25 cubic centimeters of gasoline and kerosene, and from 2 to 3 cubic centimeters of a 75 per cent solution (approximately saturated) of sodium chlorate. Of course, the smaller the quantity of solution, the less the danger of injury to surrounding grass. With the exception of sodium chloride (common salt) and arsenic pentoxide, all these materials were tried also on a limited number of individual plants growing under lawn conditions, and with similar results.

On small groups of vigorous dandelions growing under field conditions, ammonium sulfate, Ammo-Phos A, Cyanamid, Nitrophoska, and sodium nitrate were also compared. Each was applied at the rates of 2 and 4 teaspoonfuls per plant. In this test, none of the materials, not even in the heavier application, gave complete control. Ammonium sulfate and Cyanamid were among the most effective. None was equal to the most effective agents mentioned in table 6. In these spotting tests, as in the cutting tests, the dandelions usually recovered unless the root was destroyed to a depth of 5 or 6 inches (fig. 11).

RECURRENCE OF DANDELIONS

A dense stand of grass is the best insurance against the establishment of dandelion seedlings. If, in the eradication of dandelions, fertilizer is used as the eliminating agent, it will stimulate the grass and thus make the re-establishment of dandelion seedlings more difficult. If a nonfertilizing agent, like iron sulfate, is used, the series of treatments should be followed by liberal fertilization in order to hasten the establishment of a thick stand of grass. In either event, dandelions will re-establish themselves eventually if old plants abound in adjoining territory. Typical heads were found on the average to contain 286 seeds. A single plant, therefore, with as many as 35 stems, which is not at all unusual for a thrifty individual in waste places, might produce as many as 10,000 seeds.

Remoteness of a lawn from established dandelions does not ensure immunity from subsequent contamination, because the seed is well adapted to wind distribution. The relatively large surface exposed in proportion to the weight of the seed enables it to float easily and to be carried long distances even in a moderate wind. According to Weaver and Clements (12) the seed of dandelions may remain aloft indefinitely in a breeze of only 2 miles per hour. Dandelion seeds apparently have no resting period. They may begin to grow as soon as they come into contact with the soil if the environmental conditions are conducive to germination and space is available in which the seedlings can develop. Some protection against re-establishment is afforded by high mowing.

FERTILIZER TREATMENT NOT UNIVERSALLY ADAPTED

In these tests, the ammonium sulfate was always applied as a dry salt, in the later years mixed with 10 times its weight of sand. It was put on in the early morning while the grass was wet with dew. If the material could be applied as a spray with equally good results, the adaptation of the method would be greater. In 1935 and again in 1936, tests were conducted in which the sulfate was applied in the same quantity and with the same frequency as in the modified procedure already mentioned, but in solution. In neither year was the control obtained quite as effective as that usually obtained from the use of the dry salt. It was, however, quite satisfactory, as shown in figure 12.

Fig. 12.—Dandelion treated with ammonium sulfate in solution at the rate of 6 pounds per 1,000 square feet at regular intervals (2 weeks) throughout the summer of 1935 (right); untreated plot (left)

Photographed May 9, 1936

SUMMARY

Dandelions were killed in one season without serious permanent injury to the grass by dusting with ammonium sulfate at the rate of 6 pounds per 1,000 square feet at 2-week intervals beginning in May when or a little before the dandelions came into bloom. A total of 8 to 10 applications was made. Fertilizers like Ammo-Phos A, Nitrophoska, and sodium nitrate can be substituted for ammonium sulfate.

Fertilizers kill the dandelions not by changing the reaction of the soil, but by repeated defoliation and consequent exhaustion of the food reserves stored in the roots.

The growth of grass in the first year after the liberal use of various fertilizers exceeded the combined growth of grass, clover, and dandelions on the untreated area 4 to 36 per cent. In the second year after treatment, the growth was less.

The use of fertilizers is not satisfactory on areas infested also with crabgrass, for fertilizers stimulate unduly the growth of this hot-weather annual.

Arsenic pentoxide is effective for killing dandelions, but it remains to be demonstrated whether details of application can be so perfected that this material can be used successfully for the killing of areas of dandelions without serious permanent injury to the grass.

Ammonium thiocyanate is effective and can be used successfully on individual dandelion plants. Whether it can be used for the killing of dandelions in a wholesale way without serious injury to the grass has not yet been determined.

Dandelions were killed by repeated sprayings with iron sulfate (copperas), 1½ pounds per gallon of water, applied at the rate of 3⅓ gallons per 1,000 square feet. On areas badly infested with crabgrass, it is advisable to begin the defoliation with iron sulfate and complete it with some fertilizer like ammonium sulfate. This procedure avoids the use of an undue quantity of fertilizer and, hence, an undue stimulation of crabgrass.

Dandelions were killed with little permanent injury to the grass by 21 weekly sprayings with a one-half per cent solution of sodium chlorate.

Unless dandelions are small, cutting off the roots to a depth of less than 4 or 5 inches is usually ineffective. Cutting off the roots in May was more effective than cutting in September or October.

As an average of 4 years, the percentage of dry matter decreased gradually from winter to late April or early May, then increased progressively with the advance of the season until late summer. The decline in percentage of dry matter resulted from a decrease in sugars and easily hydrolyzable carbohydrates, and this decrease occurred at the time of the formation and early growth of new leaves. As soon as many leaves were fully developed, storage of reserves began. Probably the plants are weakest when the reserves are lowest. Treatments intended to exhaust plants should, therefore, be started at that time.

Individual plants were killed by the use of various materials. A saturated solution of sodium chlorate is most effective. On account of the relatively small quantity required, little of it spreads to and kills the surrounding grass.

If some nonfertilizing agent like iron sulfate is used for the elimination of dandelions, the treatments should be followed by liberal fertilization to promote the spreading of the grass.

Some evidence has been accumulated that ammonium sulfate can be applied successfully in solution as well as in the form of a dry salt. More information regarding details of this method is needed, however.

WHAT OTHERS RECOMMEND

Within the last few years, several additional methods for the control of dandelions have been proposed. Loomis (7) reports good results on Kentucky bluegrass – white clover lawns from the use of what he calls straight-run kerosene (boiling point 350 to 480° F., unsaturated hydrocarbon content 4 per cent or less) applied at the rate of approximately 5 gallons per 1,000 square feet during cool cloudy weather, preferably 2 months before the end of the bluegrass growing season, about September 15 or later. Bluegrass, as well as dandelions, he says, will be killed if more than about 7 gallons of kerosene are used, if furnace or tractor distillates are used instead of kerosene, and if the spray is applied too late in the fall to permit the grass to make a partial recovery before winter.

Hanley and Weinard (2) reported better results from ethyl 9-acetoxy mercuri 10-methoxy stearate (mercurated ethyl stearate) dissolved in kerosene than from kerosene alone or from three other materials, iron sulfate, copper nitrate, and Ammo-Phos. They recommend that approximately 12 cubic centimeters of the mercurated ethyl stearate be dissolved in a gallon of kerosene; that the solution be applied at the rate of at least 5 gallons per 1,000 square feet, preferably from mid-June to late July, and in the late afternoon or evening during humid cloudy weather; and that the grass be short.

Considerable attention has been and is being attracted to a preparation manufactured by Armour and Company and sold by them under the trade name of MEO-181. This material is said to be effective on dandelions and many other weeds, particularly those whose roots contain latex. It is recommended that this agent be applied as a spray at the rate of 5 gallons per 1,000 square feet when the grass is dry. A rain a few hours after application is said not to be harmful, however.

The Ohio Station has tried each of these materials in a limited way. Whether the use of any of them will give satisfactory results under Ohio conditions remains to be determined. More trials are in progress.

BROAD-LEAVED PLANTAIN, DOORYARD PLANTAIN, BIRDSEED PLANTAIN (*PLANTAGO MAJOR* L.)

CHARACTERISTICS

Broad-leaved plantain is a perennial reproducing by seed. The plant, figure 13, is so universally distributed that it is generally recognized by all.

Fig. 13.—Broad-leaved plantain

CONTROL

Broad-leaved plantain was eliminated by the use of the same materials, applied in the same manner, as recommended for dandelion. It is less persistent and more readily killed than dandelion.

BUCKHORN, NARROW-LEAVED PLANTAIN, ENGLISH PLANTAIN, RIBWORT (*PLANTAGO LANCEOLATA* L.)

Buckhorn is perhaps as generally distributed and universally despised as the dandelion. It, too, therefore, is given relatively large space in this publication. Some habits of growth, as well as experimental measures of control, are presented. People concerned only with control procedures may pass directly to the summary, page 37.

CHARACTERISTICS

Buckhorn, figure 14, is usually classified as a perennial; sometimes, as a biennial or even an annual. It reproduces by seed and is said to propagate also by sending out new shoots from the roots.

Fig. 14.—Buckhorn in bloom

CONTROL

HAND WEEDING

If the number of plants is limited, it is practical to remove them by hand. Midsummer is the best time for hand weeding, for in July and August the plants are usually looser in the ground than they are either earlier or later in the season. If the entire fleshy part of the root is not lifted, the depth to which it is cut off is important. On August 7, 1933, crowns were removed to a depth of ¼, ½, and 1 inch. Practically all those cut to a depth of ¼ inch sprouted, as shown in figure 15. Good control was obtained only where the cutting was made to a depth of 1 inch.

CHEMICALS

Repeated experiments have shown that buckhorn can be eliminated with various chemicals in much the same manner as dandelions. Buckhorn leaves, unlike those of dandelions, remain green throughout the year, and the treatments can, therefore, be made successfully during the late fall and winter.

In the use of chemical agents, tests were planned to determine the best combination of quantity of material and number of applications for killing buckhorn with a minimum of injury to the grass. To facilitate even distribution, the compounds were mixed with 10 times their weight of sand. The areas contained 100 square feet.

Nitrophoska

On a lawn area badly infested with buckhorn, a series of plots was treated with Nitrophoska in the fall of 1931. The plot on which best results were obtained was dusted at the rate of 10 pounds per 1,000 square feet on each of the following dates: October 30, November 25, and December 24, 1931, January 25 and February 24, 1932. On May 27, 1932, a count was made of the buckhorn plants remaining on the treated plot and on an adjoining untreated area. The results showed a control of 93 per cent. The difference in appearance between the two areas June 18, 1932, was striking (fig. 16, A). On a second area where the original stand of buckhorn plants was less than on the one already described, a similar series of treatments in the winter of 1932-1933 gave a control of 97 per cent. In a third set of tests, made in the summer of 1932, in which the Nitrophoska was applied at approximately monthly intervals from May 24 to September 12 inclusive, also at the rate of 10 pounds per 1,000 square feet, a control of 92 per cent was obtained. Reseeding was unnecessary where the precaution was taken to pulverize the Nitrophoska.

Fig. 15.—Crown of buckhorn plant cut off to depth of one-fourth inch

The cutting did not kill.

Ammo-Phos A (Ammonium Phosphate)

A lawn area on which there was a profusion of buckhorn plants was dusted with Ammo-Phos A at the rate of 6 pounds per 1,000 square feet on each of the following dates: November 4 and December 2, 1931, January 7, February 12, and February 29, 1932. A count of plants in May 1932 on the treated plot and on an adjoining untreated area showed a control of 98 per cent. The contrast as it appeared June 18, 1932, was marked (fig. 16, B). Applied at the same rate and with the same frequency in the winter of 1932-1933, this material gave similar results.

Ammonium Sulfate and Iron Sulfate (Calcined)

A lawn on which the stand of buckhorn was thick was treated with a mixture of ammonium sulfate and iron sulfate, or copperas (calcined), approximately 3.50 pounds of ammonium sulfate and 1.75 pounds of iron sulfate per 1,000 square feet. The five applications were made on the same dates as were the applications of Ammo-Phos A. In May 1932 they showed a control of 91 per cent, and the contrast between the treated and untreated areas was outstanding (fig. 16, C). On another lawn overrun with buckhorn, a mixture of the same materials in the same proportion was applied at the same rate November 1 and December 1, 1932, and January 3, February 2, and March 6, 1933. As a result of this series of top-dressings, a control of 98 per cent was obtained. Reseeding was not required. The elimination obtained in these tests from the use of this mixture is in agreement with the results reported by Dawson and Evans (1).

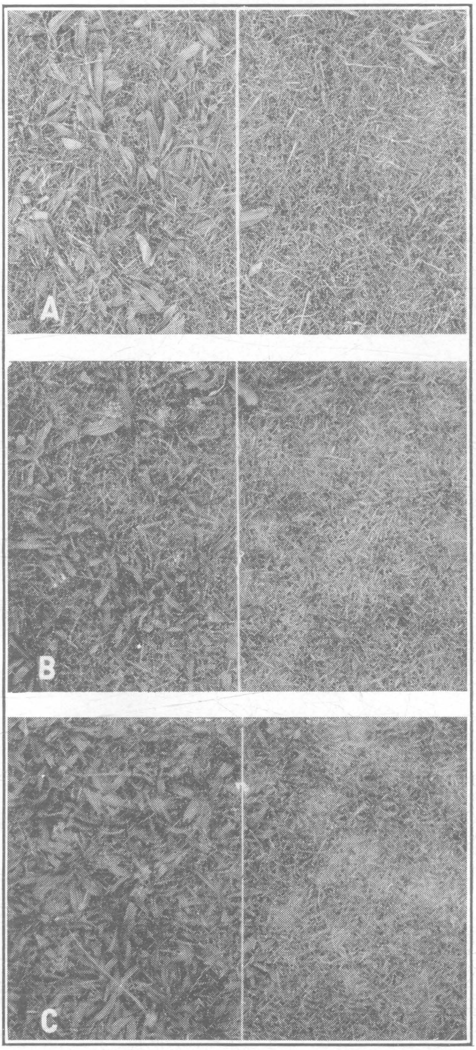


Fig. 16.—Buckhorn treated with various chemical agents in the fall and winter of 1931-1932

A—Nitrophoska (right); no treatment (left)

B—Ammo-Phos A (right); no treatment (left)

C—Mixture of ammonium sulfate and iron sulfate, or copperas (calcined) (right); no treatment (left)

Photographed June 18, 1932

Ammonium Sulfate Alone

On a lawn badly contaminated with buckhorn, a series of plots was top-dressed with ammonium sulfate, part at the rate of 8, part at the rate of 12, pounds per 1,000 square feet. The applications were made October 30, November 25, and December 24, 1931, January 25 and February 24, 1932. Five top-dressings of the sulfate at the rates of 8 and 12 pounds per 1,000 square feet gave controls of 89 and 98 per cent, respectively. The heavier rate of application resulted in considerable injury to the grass; so much that reseeding was advisable.

Cyanamid

On a lawn in which buckhorn had become thickly established, a row of plots was treated with Cyanamid at the rates of 8 and 12 pounds per 1,000 square feet on October 30, November 30, and December 28, 1931, January 25 and February 24, 1932. This material was effective in killing buckhorn, but no combination of rate and number of applications gave satisfactory results. With the heavier rate of application, which gave a control of 97 per cent, much of the grass was killed, and reseeding was necessary.

Summary of Chemical Tests

All the treatments used were effective. As agents for killing buckhorn without destruction of the grass, however, Nitrophoska, Ammo-Phos A, and the mixture of ammonium and iron sulfates[9] were the most satisfactory. In fact, the elimination of the buckhorn with any one of these three was almost complete without serious injury to the grass.

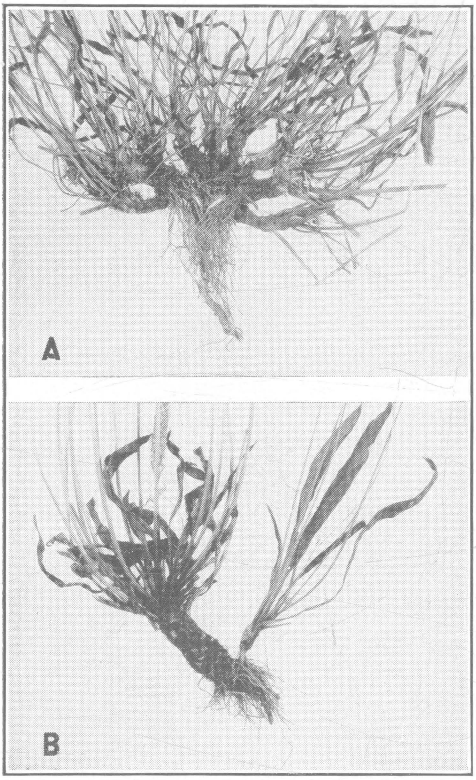


Fig. 17.—Buckhorn roots

A—Much-branched crown
B—Shoot developed from root

RECURRENCE OF PLANTS

Effective and satisfactory as the chemicals were for the elimination of buckhorn, the ultimate results were disappointing, for in most places the ground was reoccupied sooner or later with new plants. Recurrence of many kinds of weeds after treatment, especially those which seed abundantly, is common. With buckhorn this problem is accentuated by the vigor and speed with which the young plants grow and the relatively short time in which they attain prominence. It is possible for the seeds to germinate and the plants to flower and seed in a single season. If the recurrence of buckhorn is to be inhibited, an understanding of its mode or modes of propagation is essential.

It is the opinion of some that vegetative reproduction in buckhorn is not at all uncommon. Observations made at the Ohio Station, however, do not substantiate this contention. Examination of the roots of 164 1-year-old plants on June 10, 1935, revealed 3 only on which there was any indication of an incipient shoot. On five, or 3 per cent of the total, however, there were several crowns. In a group of 259 individual plants of unknown age selected at random July 27, 1933, 2 or more crowns had developed on 38, or 15 per cent (fig. 17, A). On two roots only, or less than 1 per cent, a

[9]The combination of ammonium and iron sulfates is not commercially available. The two must be mixed. The iron sulfate must be oven-dried at a temperature of about 100° C. (212° F.) before mixing.

shoot like that shown in figure 17, B was found. If these results are typical, the number of plants developed vegetatively is negligible. Most, if not all, come from seed.

Buckhorn seeds prolifically. The size of head and, hence, the number of seeds per head vary widely, depending on the fertility of the soil and the seasonal conditions. Where the plants are allowed to grow unmolested, a single head may attain a length of 3 or more inches. Heads of that size may bear 300 or 400 seeds. Nearly 300 heads gathered at random in the summer of 1937 averaged 1.42 inches in length. The average number of seeds on 20 heads of this average length was 157.

The number of seed stalks that may be produced by an individual plant in a given season is surprisingly large. In a planting of buckhorn, the primary purpose of which was to determine the longevity of buckhorn plants, the total number of stalks produced per plant was also noted. In 1931, the number ranged from 2 to 168. The average (986 plants) was 56.2. In 1932, the extremes on the plants remaining (937) ranged from 1 to 243, with 59.6 stalks as the average. In another test, started September 18, 1936, the number of stalks per plant developed in the summer of 1938 ranged from 1 to 215 and averaged 59.2 (963 plants).

The number of seeds matured on 4 individual plants with 64, 67, 46, and 86 heads apiece, was 6,422, 8,120, 7,043, and 7,462, respectively. Most of these seeds were viable, too, for the percentage of germination of each lot was 92, 94, 78, and 88. It is probable that seed production is more abundant under field conditions than under lawn conditions, for in lawns, many of the heads are clipped off before maturity. It was noted, moreover, that in periods of hot weather many heads wither and die before maturation of seed. When due allowance is made for the usual casualties, however, it is apparent that the extermination and prevention of rapid re-establishment of buckhorn involve not only the elimination of the plants themselves, but the killing of a host of seeds as well.

PREVENTION OF THE DEVELOPMENT OF SEEDLINGS

There are two possibilities for preventing the development of new plants: killing the seed already distributed, and preventing seed formation.

Experiments have shown that buckhorn seed is killed by Cyanamid. Unfortunately, however, trials with this agent have thus far failed to reveal any combination of rate and frequency of application by which the seed can be killed without serious injury to the grass. Ten weekly applications at the rate of 2 pounds per 1,000 square feet did not injure the grass severely, but neither did they eliminate the buckhorn. Yearly top-dressings at the rate of 10 pounds per 1,000 square feet destroyed most of the buckhorn, but the stand of grass after 3 years of such treatment was perceptibly thin. Until a way can be found to kill the seed without severe injury to the grass, probably the most effective procedure is to prevent the development of seed.

Needless to remark, preventing the development of seed is more easily suggested than done. Unlike those of many weeds, the seed stalks of buckhorn stand upright. Unless they are cut often, however, the ordinary lawn mower fails to behead them, because they grow rapidly.

Daily measurements were made on 100 stalks representing that number of individual plants from July 1, 1937, when they were one-half inch long, until stem elongation had ceased and blooming had finished. The average daily growth, the total period of growth, and the average time of first and last bloom are shown graphically in figure 18. The results show a progressive increase in daily growth reaching a maximum on the eighth and ninth days, after which there was a gradual decrease. Beginning with the fourth day, the elongation amounted to at least an inch per day over a period of 8 consecutive days. At the peak of growth, the rate slightly exceeded 1½ inches per day. During the period of most rapid growth, the total elongation in a 7-day period amounted to more than 9 inches. With stalks that high, clean mowing with most lawn mowers is impossible. Semiweekly or even more frequent mowings may be necessary during periods most favorable for growth. Whenever a mower fails to behead them, a scythe or sickle can be used.

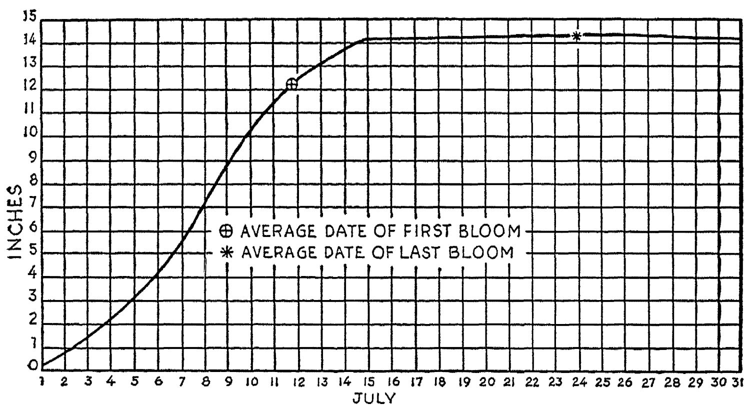


Fig. 18.—Rate of growth of buckhorn seed stalk

If the development of viable seed is to be prevented, the heads must be cut off before the last bloom disappears. Bloom develops first at the base of the head and then proceeds upward. One hundred heads were gathered just before the disappearance of the last bloom in 1936 and 1937. Viable seeds were found on 82 and 89 per cent of the heads in 1936 and 1937, respectively. The percentage of viable seeds per head ranged from 2 to 99, with an average of 33, in 1936, from 1 to 78, with an average of 30, in 1937.

In each of the same 2 years, 100 heads were gathered on which the bloom had developed to the mid-point only. Germination tests failed to reveal viable seeds on a single head in either year. From these results, it can be concluded that no mature seeds can be expected if the bloom has proceeded to the middle of the head only, but that many may be present when the last bloom is disappearing.

The speed at which blooming takes place and other facts related to the development of the seed stalk are shown in table 7.

TABLE 7.—Reproduction of buckhorn*

Development of seed stalk	Year				
	1934	1935	1936	1937	4-year average
Average number of days to first bloom	10.3	10.6	12.1	14.4	11.9
Average number of days from first to last bloom	10.9	12.8	10.4	11.7	11.5
Average total days to last bloom	21.2	23.3	22.6	26.2	23.3
Average length of stalk including head (inches)	16.1	18.8	12.1	19.0	16.5

*Records based on the performance of 100 seed stalks in 1934 and 1935, 200 in 1936, and 270 in 1937. In 1934 and 1935, however, many of the seed stalks withered and died on account of hot weather, before the completion of blooming, and the later records taken in those years are based on less than 100 individuals, 35 in 1934 and 41 in 1935. All were volunteer plants growing in sod not mowed frequently.

LONGEVITY OF SEED

Seed of buckhorn apparently retains its vitality for many years. During the 10-year period, 1928-1937, seed of buckhorn was gathered each year and preserved in glass bottles, the corks of which were sealed in with paraffin. The bottles were stored in a building heated during the winter periods. In February 1938, samples of these seeds were tested for vitality. The results obtained are shown in table 8.

TABLE 8.—Longevity of buckhorn seed

	Seed collected in—									
	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
Age when tested (years).	10	9	8	7	6	5	4	3	2	1
Germination (per cent).	55	89	86	81	67	86	81	87	95	79

With the possible exception of the 10-year-old sample, age seems to have had little, if any, effect on the vitality of the seed. Under field conditions, of course, the results might be quite different.

LONGEVITY OF PLANT

As stated before, buckhorn is variously classified as a perennial, biennial, and annual. Undoubtedly some author is correct. All may be. The apparent discrepancies may represent the response of this plant to different environmental conditions. In order to get more definite information regarding the duration of this weed under Ohio conditions, three longevity tests have been conducted at the Ohio Agricultural Experiment Station.

On May 6, 1931, 986 buckhorn seedlings were planted 6 inches apart in 10 rows 1 foot apart. These plants were prevented from seeding by removal of the seed stalk as soon as the first bloom appeared. A count of the plants was made in the spring and fall of each year. The results of these counts are shown in table 9 (1931-1934).

TABLE 9.—Persistence of buckhorn plants

Period of observation	Number of individuals													
	First year		Second year		Third year		Fourth year		Fifth year		Sixth year		Seventh year	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
1931–1934 inclusive	986	966	937	813	372	242	0	0	......	......	......	......	......	......
1934–1940 inclusive	1,000	831	815	757	13	13	11	8	6	5	4	3	3	2
1936–1940 inclusive	......	1,000	......	979	963	......	513	436	205	181	......	......	......	......

Inasmuch as some plants continued into the third year but none into the fourth, the conclusion would seem to be warranted that buckhorn is a short-lived perennial; at least it was under the conditions of this test. In the winter of 1932-1933, considerable heaving occurred. When the test was started, no grass seed was sown between the rows, and the environment was, therefore, somewhat unlike that in a lawn.

In a second experiment, 1,000 plants were space-planted in the same manner as in the 1931-1934 trial. The seedlings were transplanted to the field June 22 and 23, 1934. Seed of redtop was sown between the rows of buckhorn to simulate lawn conditions and reduce the possible damage from heaving to a minimum. The duration of the plants in this planting was as shown in table 9 (1934-1940).

In this trial, most of the plants died in the winter of 1935-1936, at the end of the second year. The heavy mortality at that time may have been due to much cold weather that winter, as the temperature was zero or below 19 times. In January, the temperature ranged from 6 to 15° below zero on 5 consecutive days. In February, there were 9 days of zero or subzero weather; the lowest temperature was 11° below. The snowfall was heavy throughout the winter, and in the latter part of February and in March, the ground was covered with ice much of the time.

In the third test, 1,000 seedlings were started September 17 and 18, 1936. They were space-planted in the same manner as in the two preceding tests. Seed of timothy was broadcast over this bed in the early spring of 1937, but the stand obtained was very thin. This test is not yet completed, but the plants are thinning out in much the same manner as did those in the other two trials. The counts to date are shown in table 9 (1936-1940).

COLD RESISTANCE

A refrigeration test showed that buckhorn is not particularly winter hardy, that it may succumb to subzero temperatures such as often occur in Ohio, and that it yields to cold more readily than does Kentucky bluegrass. In this experiment, Kentucky bluegrass sod containing many buckhorn plants was lifted to a depth of 4 inches and placed in wooden flats 15 by 22 inches in February 1938 while the plants were in a hardened condition. One series of three flats was exposed to artificial refrigeration at an air temperature of —15° C. (5° F.), one at —20° C. (—4° F.), and one at —25° C. (—13° F.). In each series, one flat was exposed one night, one two nights, and one three nights. Between times, the flats were removed from the refrigeration room and placed out of doors. After exposure, the three flats in each series were transferred to a greenhouse and placed beside a fourth, unexposed, which served as a check. The three series of four flats each were allowed to remain in the greenhouse until the middle of April, when it was evident that the full effect of the refrigeration was manifest.

Both buckhorn and Kentucky bluegrass were killed by exposures of three and even two nights at air temperatures of —25 and —20° C. (—13 and —4° F.). One night of exposure at these temperatures did not kill either the buckhorn or the grass. At the air temperature of —15° C. (5° F.), two nights of exposure killed neither the buckhorn nor the Kentucky bluegrass. Three nights of exposure at this temperature, however, killed all the buckhorn plants except one. The Kentucky bluegrass and other vegetation, such as orchard grass, white clover, broad-leaved plantain, and wood sorrel, survived.

In the winter season in the latitude of Wooster, an air temperature of —15° C. (5° F.) is not unusual. Probably the reason such a temperature does not result in a wholesale destruction of buckhorn is that the soil temperature of which it is a reflection is considerably higher in nature than it was in the artificial refrigeration test. A double soil thermograph, the thermometers of which were buried to a depth of 1 inch in the winters of 1924-1925 and 1925-1926, showed that when the air temperature was approximately 5° F., the soil temperature was about 29° F. Even with an air temperature of 5° below zero F., the soil temperature averaged about 22° F. above. In the artificial refrigeration test, the soil temperature accompanying the air temperature of —15° C. (5° F.) descended to —12° C. (10.4° F.).

In northern latitudes, it is probable that the soil temperature frequently descends to 10° F. or even lower. If buckhorn is really not hardy, it could hardly be expected to persist long in those regions. With this idea in mind, the authors sent a letter of inquiry about the prevalence and persistence of buckhorn to several agricultural institutions in northern latitudes.

The significant comments follow:

From Idaho: "Buckhorn, *Plantago lanceolata,* is not a serious weed under our conditions."

"Buckhorn, *Plantago lanceolata,* is not yet a problem in Montana. It has been collected in the State but for some reason has not gained a firm foothold."

"Buckhorn, *Plantago lanceolata,* is not a problem in North Dakota. It is extremely rare that we see it here. This can certainly be taken as evidence that it is not adapted to our region since the seeds must have been repeatedly introduced with red clover."

From Michigan: "Buckhorn is a very serious pest in lawns in the southern half of this State but is not nearly so abundant in the northern half."

From New Hampshire: "We may be wrong in assuming so, but we have been regarding buckhorn, or *Plantago lanceolata,* as an annual weed. It is not a serious pest in cultivated fields but assumes a great deal of importance on lawns in our State."

"Buckhorn, *Plantago lanceolata,* is not a serious problem in Maine. It apparently does not survive our climatic conditions."

"Buckhorn is occasionally found in lawns and pastures in this Province (Saskatchewan) but so far it has not been reported as a troublesome weed. Weed bulletins in Alberta and in Manitoba do not list it either."

"Occasionally plants of it (buckhorn) have been introduced here (Alberta, Canada) but it is little known. I would think that such buckhorn plants as occur in Alberta are of the current season's growth."

"Buckhorn, *Plantago lanceolata,* is not a problem in Alaska either in meadows or on lawns. So far as we know buckhorn is not found in Interior Alaska."

SUMMARY

Hand weeding of buckhorn is best done in July and August, for at that season the plants are loose in the ground. Cutting through the crown is not effective unless it is done to a depth of at least 1 inch.

Over 90 per cent control was obtained by monthly treatments from October to February inclusive, of Nitrophoska applied at the rate of 10 pounds per 1,000 square feet; of Ammo-Phos A at the rate of 6 pounds per 1,000 square feet; of a mixture of ammonium sulfate and iron sulfate, or copperas (calcined), approximately 3.5 pounds of the former and 1.75 pounds of the latter per 1,000 square feet; of ammonium sulfate alone at the rate of 12 pounds per 1,000 square feet; of Cyanamid at the rate of 12 pounds per 1,000 square feet. Nitrophoska, Ammo-Phos A, and the mixture of ammonium and iron sulfates were the most satisfactory. No reseeding was necessary after the use of them, but some was required after the other two. Results from chemical treatments were disappointing, because new plants soon came in from seed.

Vegetative reproduction in buckhorn is not very common. Less than 2 per cent of the roots of 164 1-year-old plants showed evidence of propagating vegetatively. Less than 1 per cent of the roots of 259 plants of unknown age developed a branch.

The number of seeds per head on buckhorn varies widely, depending on the size of the head. Heads approximately 1½ inches long may carry around 160 seeds. On over 900 individual plants, the number of heads per plant averaged 56.3 in 1931, 59.5 in 1932, and 59.2 in 1938. The number of seeds per plant varies with the number and size of heads. Four individuals averaged per plant 65.8 heads and 7,261 unshriveled seeds. The germination of these seeds averaged 88 per cent.

Buckhorn seeds were killed with Cyanamid, but no method of application has yet been found whereby both the plants and seed can be killed without injury to the grass.

The rate of growth of the buckhorn seed stalk varies, depending on the age. At the period of maximum rate of growth, it may equal or even exceed 1½ inches per day. Germination tests showed that by the time the last bloom was disappearing from the tip of the head, viable seed had already formed at the base. The approximate number of days from the start of seed stalk to first bloom was 11.86, from first to last bloom, 11.48. The average length of seed stalk, including head, was 16.5 inches.

Buckhorn seed may retain its vitality for at least 10 years.

Under conditions such as prevail at Wooster, buckhorn behaves as a short-lived perennial. In one test including 986 individual plants, all were dead by the fourth year. In a second test, including 1,000 plants, all but 13 were dead by the third year. A few of the remaining plants persisted through the seventh year. Even though buckhorn may be a short-lived perennial, it does not follow that the prevention of seed production for 3 or 4 years will result in its elimination, for it is not known how long the seed may lie dormant in the soil.

Artificial refrigeration tests showed that buckhorn is less winter hardy than Kentucky bluegrass; that it succumbs at a soil temperature of —12° C. (10.4° F.). Correspondence with agricultural institutions in northern latitudes revealed that in those regions buckhorn is not a serious problem.

CRABGRASS (*SYNTHERISMA SANGUINALE* L.)

As a lawn pest crabgrass ranks with the dandelion and buckhorn. Probably this trio is responsible for more headaches than all the other lawn weeds combined. Because of its prominence, some aspects of the plant and seed development as well as control measures, are discussed. Individuals wishing to avoid details and caring only for control recommendations may proceed immediately to the summary, page 45.

CHARACTERISTICS

Plant.—Crabgrass is a summer annual reproducing by seed. The seeds germinate in late spring, and the plants become prominent in July and August. With the coming of cool weather in the fall, they become purple, then brown, and finally die, leaving an abundance of seeds from which new plants may start in following years. In the mature stage, crabgrass plants can be recognized easily from the slender fingers, 3 to 12, arranged in a loose whorl at the tip of the stems, figure 19. Under close mowing, the fingers may be inconspicuous, but, nevertheless, they develop, and can be detected near the ground. The plant thrives in hot weather, is aggressive, develops roots at joints in semiprostrate stems, and under good growing conditions may reach a spread of as much as 4 feet (fig. 20). In wet seasons or with liberal watering in dry summers, this grass often causes much injury to a lawn.

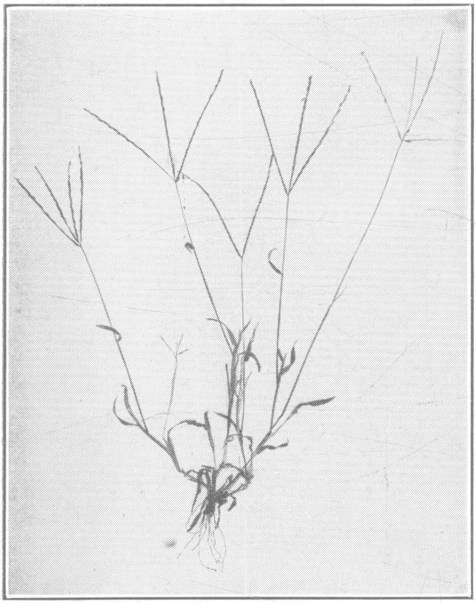


Fig. 19.—A mature plant of crabgrass

Seed.—Crabgrass seed does not germinate promptly after maturity. Samples gathered in September of 1936, 1937, and 1938 were placed under conditions favorable for germination at monthly intervals after harvest. In each of these 3 years, there was a period of dormancy, the duration of which ranged from 3 to 6 months.

Crabgrass seed requires a relatively high temperature for germination. In tests made at different temperatures, the extremes ranged from 15 to 40° C. (59 to 104° F.) with the optimum at about 30° C. (86° F.). Since a minimum temperature of approximately 15° C. (60° F.) is required for the starting of crabgrass seed, the appearance of seedlings cannot be expected until late in the spring. In the latitude of Wooster, Ohio, seedlings ordinarily begin to appear in the latter half of May. In a very warm spring, they may appear earlier.

In 1938, seedlings were noted in April. In that year, a maximum temperature of 21° C. (70° F.) or more was attained a half-dozen times in the last half of March.

The germination of crabgrass seed may be inhibited by lack of soil moisture. Crabgrass seed was planted in pots of Wooster silt loam soil containing varying quantities of moisture, 6, 8, 10, 12, 14, 16, 18, and 20 per cent. No seed germinated where the moisture content was less than 10 per cent. At 10 per cent and above, seed germinated, and the percentage of germination increased as the moisture content of the soil increased.

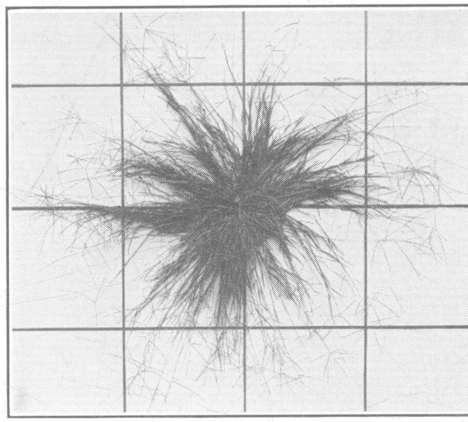


Fig. 20.—A single plant of crabgrass 4 feet from tip to tip

Under field conditions, crabgrass seed has repeatedly failed to germinate, even in warm weather, when the moisture content of the surface soil was only 7 or 8 per cent. In the drouth year of 1934, when the rainfall at Wooster for the entire month of May was 0.43 inch (50-year average = 3.73 inches), crabgrass was noticeably inconspicuous, especially in the early part of the season. In the same year in a lawn watering experiment, practically no crabgrass appeared on the unwatered or check plots, but on the plots watered artificially and separated from the unwatered by a space of only 2 feet, crabgrass was abundant.

In weekly seedings in three seasons, 1936, 1937, and 1938, the time from planting to maturation of seed ranged from 42 to 60 days. In these tests, viable seeds were sometimes produced as early as July 24 and on plantings made as late as the middle of August.

CONTROL

SODIUM CHLORATE

Crabgrass can be killed with sodium chlorate. If the treatment is started early while the crabgrass is young (one or two leaves) the crabgrass can be killed by repeated sprayings with a dilute solution without serious permanent injury to the desired grasses.

In the summer of 1930, five plots, each 5 by 20 feet, were sprayed with a one-half per cent solution of sodium chlorate used at the rate of 10 gallons per 1,000 square feet. Sprayings were made weekly from June 19 through July 25. The number of sprayings made was six, five, four, three, and two on plots 1, 2, 3, 4, and 5, respectively. The control increased with each added spraying. On the plot sprayed six times, three crabgrass plants only remained in the fall.

A disadvantage of this method of control is that the chlorate temporarily discolors the permanent grasses. This discoloration, moreover, occurs at a time of the year when the beauty of the lawn is most desired. In the fall, the discoloration disappears. In fact, the color and vigor of the grass on the test plots resembled the appearance that might be expected from a recent application of nitrogenous fertilizer.

To reduce the period of discoloration to a minimum, the spraying can be deferred until late August or the first of September, but at the more mature stage a stronger solution is required. Two applications, 1 week apart, of a 1 per cent solution or one application of a 2 per cent solution was required to kill the crabgrass plants at the later stage of development. In these strengths, particularly the latter, considerable grass was killed, and partial reseeding was necessary. A few days before seeding, the ground should be fertilized liberally. Aside from severe injury to the grass, a second disadvantage of late spraying is that viable seeds may have been produced already and disseminated.

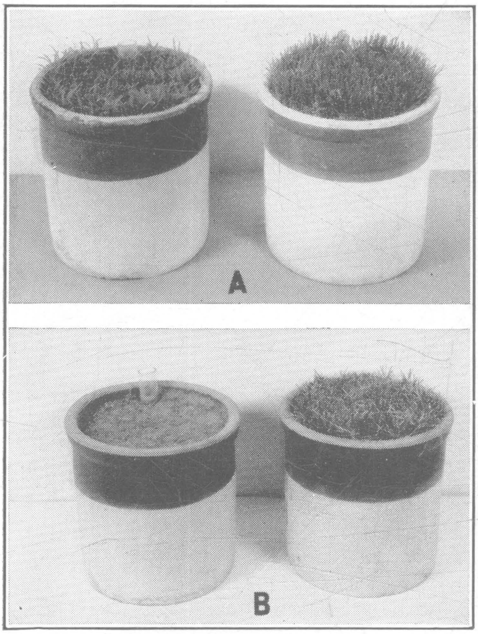


Fig. 21.—A—Crabgrass (left) and Kentucky bluegrass (right) before shading
B—After shading 10 days

SHADING

Crabgrass is relatively nontolerant to shade and, hence, succumbs to continued shading. Crabgrass and Kentucky bluegrass were established in gallon jars in a greenhouse. After the grasses had attained a height of approximately 1 inch, both were placed in a box and covered with black garden mulch paper for 10 days. At the end of this period, all the crabgrass was dead. The Kentucky bluegrass was discolored but still alive, and it revived. The contrast in appearance between the two jars of grass before and after shading was as shown in figure 21.

On a part of the Experiment Station Campus badly infested with crabgrass, eight small areas, each 3 by 4 feet, were covered with black garden mulch paper. For convenience in handling, the mulch paper was fastened with nails and cleats to wooden frames 2 inches wide. The shades were placed in position July 2, 1932. At that time, the crabgrass plants were small, having only two or three leaves. The shades were removed at 2-day intervals. Areas 1, 2, 3, 4, 5, 6, 7, and 8 were shaded 2, 4, 6, 8, 10, 12, 14, and 16 days, respectively. At the conclusion of the test no crabgrass plants were found on the areas shaded 10 or more days, and only three were found on the one shaded 8 days. The bluegrass was discolored, badly bleached on the areas covered for the longer periods. Even that covered for 16 days, however, revived.

The time required to kill crabgrass will vary with the stage of its development at the time of shading. As soon as the leaves are dead, the cover can be removed with safety, for this plant cannot send up new shoots from the roots. Kentucky bluegrass, on the other hand, can sprout from its rootstocks even though some of the leaves may have been killed from the shading.

Tar roofing, building paper, or any kind of paper impervious to light can be used. The paper is best held in position by the use of weights placed at the edges or joints. This method of killing crabgrass is, of course, not practical on large areas. Neither is it suitable for use on small areas unless the location is such that temporary discoloration of the grass is not particularly objectionable.

RAKING AND CROSS-MOWING

Much can be accomplished in the late summer by raking and mowing, first in opposite directions, then at right angles. If the refuse is collected in a grass catcher and burned, most of the seeds will be destroyed. On an area thus curried one fall, the reduction in crabgrass plants was apparent for several seasons. Collection of seed heads is facilitated by discontinuing mowing for a few weeks in the late summer. Without close mowing, the seed heads tend to stand upright and can be cut off and gathered without much raking.

HEIGHT OF MOWING

Repeated tests have shown that low mowing favors the growth of crabgrass. In a height of mowing experiment in which the grass was clipped at four different levels, ½ inch, 1 inch, 1½ inches, and 2 inches, the stand of crabgrass was noted. The number of plants at the close of three seasons, expressed in terms of plants per 1,000 square feet, was as shown in table 10.

TABLE 10.—Effect of height of cutting on the stand of crabgrass

Height of mowing	Number of crabgrass plants per 1,000 square feet						
	Actual				Relative		
	1935	1936	1937	3-year average	1935	1936	1937
Inches							
½	3,846	10,740	7,643	7,410	100	100	100
1	3,731	9,723	6,754	6,736	97	91	88
1½	2,371	5,589	4,203	4,054	62	52	55
2	1,837	2,537	1,759	2,044	48	24	23

It can be seen that in each year the number of plants decreased progressively with increase in height of cutting. The number on the ½-inch mowing ranged from two to more than four times that on the area cut 2 inches high. The spread increased with each succeeding year.

FERTILIZATION

Being an annual, crabgrass cannot easily gain a foothold each summer among old and well-established plants of the desirable grasses if they are thick and vigorous. Reappearance of crabgrass year after year indicates a thin stand of relatively unthrifty grass, and this condition is usually a reflection of unfavorable soil conditions. The basic remedy, therefore, is to improve the soil. Much can be accomplished through the use of fertilizer.

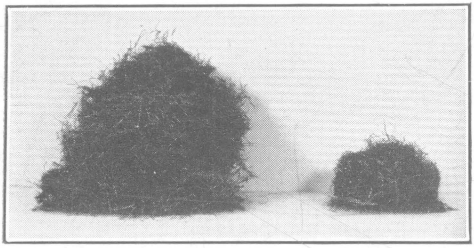


Fig. 22.—Crabgrass harvest on equal areas unfertilized (left) and fertilized with poultry peat (right)

In the fall of 1935, the crabgrass plants were removed from two equal and adjoining areas each 5 by 5 feet. One had received no fertilizer, the other had been top-dressed twice with poultry peat,[10] each time at the rate of 200 pounds per 1,000 square feet. The first top-dressing was made October 30, 1933; the second, April 23, 1935. The air-dry weight of the crabgrass on the unfertilized and fertilized areas was 235 and 59 grams, respectively. The difference in volume was as illustrated in figure 22. The reduction of crabgrass on the fertilized to approximately one-fourth that on the unfertilized area was undoubtedly due to a thickening of the stand of desirable grasses as a result of the top-dressing of fertilizer.

In fertilizing to control crabgrass, the applications should be made in the fall or very early spring. Late spring and midsummer applications should be avoided, for these stimulate the crabgrass, and the crabgrass thus stimulated may crowd out the desirable grasses, figure 23.

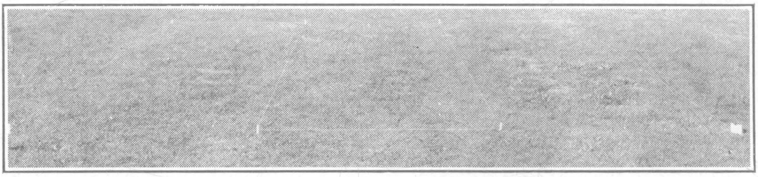


Fig. 23.—Part of a series of lawn plots fertilized on different dates, May (left), June (middle), and July (right)

The fertilizer stimulated the growth of crabgrass to the detriment of the Kentucky bluegrass to a greater extent on these than on other plots in the series fertilized either earlier or later in the season.

HEIGHT OF MOWING AND FERTILIZATION COMBINED

Liberal fertilization and high mowing are an effective combination for the control of crabgrass. Eight plots, each 5 by 10 feet, were selected on the Experiment Station Campus in the fall of 1935 for the purpose of mowing in subsequent years at two levels, 3 inches and ½ inch. The two heights were to

[10]Poultry peat is a mixture of poultry manure and peat obtained by using peat as litter in poultry houses.

TABLE 11.—Combined effect of height of cutting and fertilization on stand of crabgrass

Year	Number of crabgrass plants per 1,000 square feet							
	Actual				Relative			
	Unfertilized		Fertilized		Unfertilized		Fertilized	
	Low	High	Low	High	Low	High	Low	High
1936	14,570	11,760	17,830	13,610	100	81	100	76
1937	13,150	3,900	15,040	1,940	100	30	100	13

be alternated. Two pairs of the proposed high and low clipping plots were fertilized with poultry peat at the rate of 200 pounds per 1,000 square feet on November 20, 1936. These two pairs of fertilized plots alternated with the two like pairs of unfertilized ones. In the late fall, crabgrass seeds were sown on all the plots. At the close of the mowing season in 1936 and again in 1937, the number of crabgrass plants on each plot was counted. The results, expressed in terms of plants per 1,000 square feet, were as shown in table 11.

The contrast in density of stand between crabgrass mowed low and high was very marked in the fall of 1937 on both the unfertilized and fertilized areas.

RESISTANCE OF GRASSES

Apparently, some grasses are more resistant than others to the encroachment of crabgrass. Two parallel strips were seeded October 14, 1932, one with South German mixed bent at the rate of 4 pounds, the other with a standard mixture of Kentucky bluegrass and redtop at the rate of 5 pounds per 1,000 square feet. Three years later a considerable quantity of crabgrass had gained a foothold in the standard mixture, but very little had come in with the bent. The contrast between the strips, as it appeared October 19, 1935, was very marked (fig. 24).

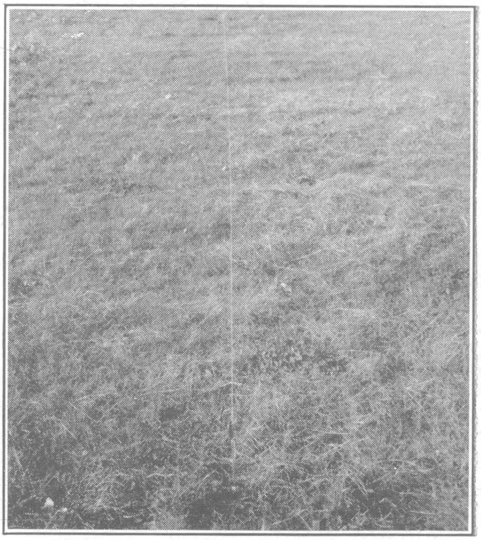


Fig. 24.—South German mixed bent (left); standard mixture (right)

Among the bents themselves, there is considerable difference in resistance to the establishment of crabgrass. Three parallel strips were seeded October 1, 1931, each at the uniform rate of 4 pounds of seed per 1,000 square feet. Four years later much crabgrass had become established in the Prince Edward Island bent, but little had come in with either the New Zealand browntop or the South German mixed bent. The contrast, as it had developed by November 1, 1935, was pronounced (fig. 25).

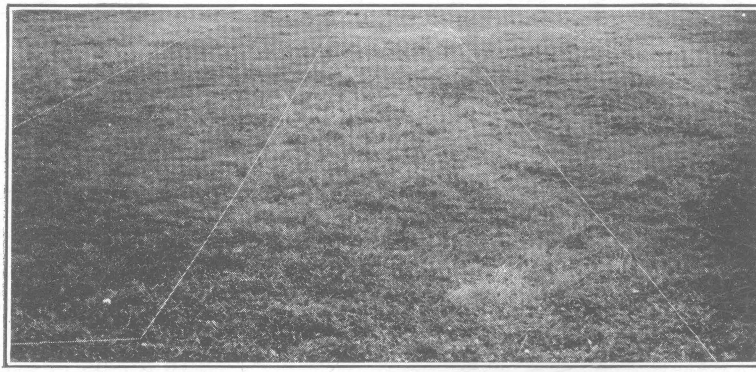


Fig. 25.—New Zealand Browntop (left), Prince Edward Island bent (middle), South German mixed bent (right)

Apparently, some of the fescues also resist the establishment of crabgrass. In experimental plots representing different species and different mixtures of species, growing side by side, it was observed that the ones seeded to the fescues alone or to mixtures in which the fescues predominated contained relatively little crabgrass.

LEAD ARSENATE

During the period 1930-1937, the Ohio Agricultural Experiment Station conducted experiments in the use of lead arsenate as an agent for the control of crabgrass infesting lawns of Kentucky bluegrass. In most tests where this material was distributed evenly at the rate of at least 20 pounds per 1,000 square feet sometime between October and March, a control of 95 per cent or more was obtained. Moreover, the control was lasting. The first test was made in 1930. The effect of this treatment, which was made at the rate of 35 pounds per 1,000 square feet, was still evident in the fall of 1940.

Unfortunately, the treatments have resulted in some discoloration of the grass. This effect has not shown up until a year or more after the application of the material. Lead arsenate treatments have also reduced the growth of grass somewhat. These two disadvantages have been largely overcome by the use of organic nitrogenous fertilizer in a quantity that supplies approximately 5 pounds of nitrogen per 1,000 square feet. A moderate application of a fertilizer like a 10-6-4 has not brought about a satisfactory recovery promptly.

Numerous reports that lead arsenate gave little or no control have been received by the Ohio Station. The details attending the execution of these unsatisfactory tests were in most instances more or less obscure. At least in some cases, however, the unsatisfactory results were obtained on neutral or alkaline soil. The Station Campus, where successful tests were made, is moderately acid. The reaction of the soil, therefore, may be an important consideration in the success or failure of this material in controlling crabgrass.

Conceivably, the plant itself may be a factor, for there are more than one species. On the Station Campus, the large, *S. sanguinale*, predominates. The small, *S. ischaemum*, appears to be more abundant in latitudes farther south.

Until more is known about its limitations, lead arsenate is not recommended unqualifiedly. Mention of the method is made in the hope that the promising results thus far obtained may serve as a stimulus to others to try lead arsenate in a small way so that the limitations of the procedure may be determined soon.

SUMMARY

Crabgrass was killed by six weekly applications of a one-half per cent solution of sodium chlorate used at the rate of 10 gallons per 1,000 square feet. Applications were begun June 19, when the seedlings had only one or two leaves. The period of discoloration of the lawn grass was shortened by deferring treatment until late August or the first of September. At the more mature stage of growth, two applications of a 1 per cent solution a week apart or one application of a 2 per cent solution was required. Some reseeding was necessary.

Crabgrass was killed by shading with black garden mulch paper for 10 days. The bluegrass was discolored but not killed; even that covered for 16 days revived.

Repeated rakings and cross-mowings with removal of clippings in late summer before the maturation and scattering of seed, eliminated crabgrass plants to such an extent that the reduction in stand was perceptible for several years.

Low mowing favored the development of crabgrass. When the number of crabgrass plants found on an area mowed one-half inch high was considered as 100 per cent, the number on equal and adjoining areas mowed 1 inch, 1½ inches, and 2 inches was 97, 62, and 48 per cent, respectively, in 1935; 91, 52, and 24 per cent, respectively, in 1936; and 88, 55, and 23 per cent, respectively, in 1937.

The air-dry weight of crabgrass in the fall of 1935 on an area fertilized October 30, 1933, and again April 23, 1935, was 25 per cent of that on an equal and adjoining but unfertilized area.

The combined effect of high mowing and fertilization was very marked. The percentage of crabgrass on the high- as contrasted with the low-mowed plots was 81 and 30 per cent in 1936 and 1937, respectively, on the unfertilized, and 76 and 13 per cent on the fertilized plots.

From observation, it appears that certain of the bent and fescue grasses offer more resistance to the coming in of crabgrass than does Kentucky bluegrass.

In repeated tests, lead arsenate has given a control of at least 95 per cent. Control may continue at least 10 years. Unfortunately, the use of lead arsenate has resulted in a slight yellowing of the grass and in a restriction of its growth.

GROUND IVY, GILL-OVER-THE-GROUND, CREEPING CHARLIE (*GLECOMA HEDERACEA* L.)

CHARACTERISTICS

Ground ivy is a creeping perennial which reproduces by seed and by rooting at the nodes in the stems (fig. 26). The rounded and scalloped leaves are green on both sides, and clusters of purplish flowers appear in early summer. The plant has a pungent odor. Ground ivy flourishes in shady places and when not mowed often may cover the ground completely. On account of its trailing habit of growth, the plant becomes so entwined with the grass that eradication by digging it up, even on small patches, is impractical.

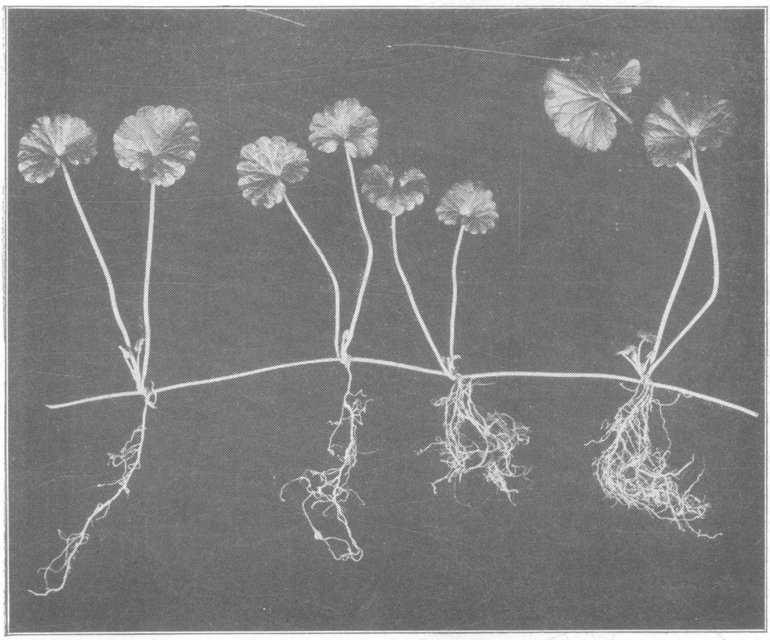


Fig. 26.—Ground ivy, nature of growth

CONTROL

Repeated experiments have shown that ground ivy can be eliminated either in winter or summer by one spraying with sodium chlorate, 1 ounce per gallon of water, applied at the rate of 7 gallons per 1,000 square feet. A thorough wetting of the leaves can be better effected with a pressure sprayer than with a sprinkling can. An untreated and treated area are shown in figure 27.

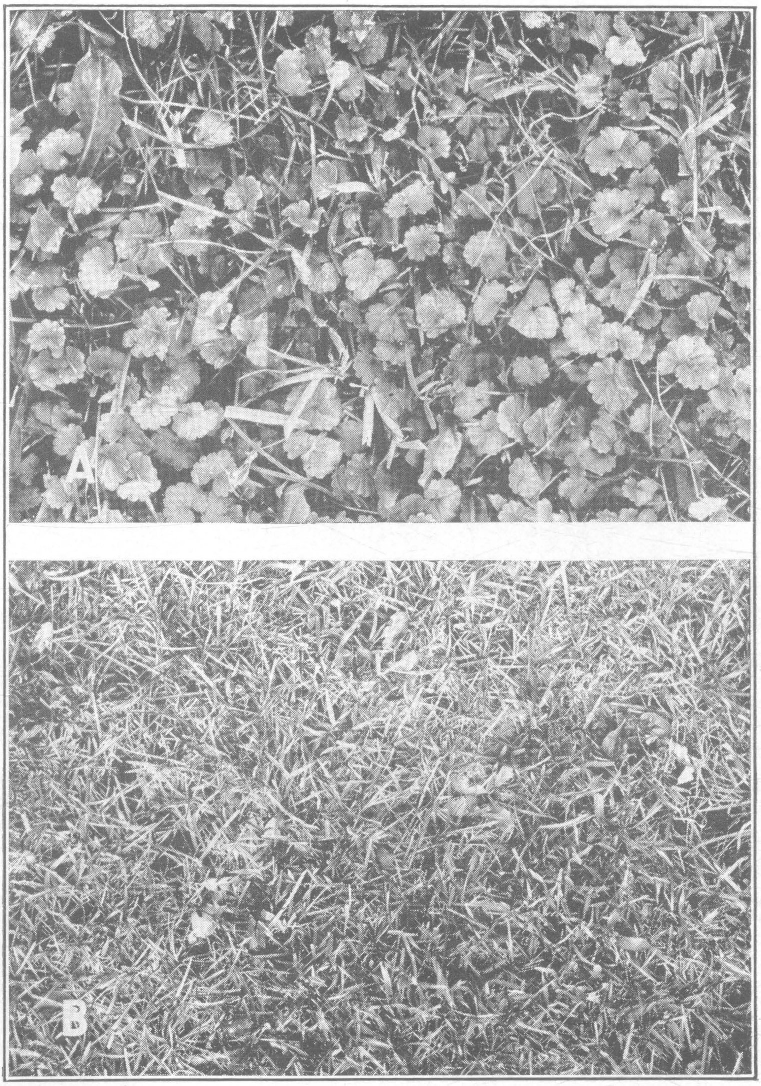


Fig. 27.—Ground ivy

A—Unsprayed
B—Sprayed once with sodium chlorate

THYME-LEAVED SPEEDWELL, CREEPING SPEEDWELL (*VERONICA SERPYLLIFOLIA* L.)

CHARACTERISTICS

Thyme-leaved speedwell is a perennial reproducing by seed and by rooting at the nodes of the much-branched and prostrate stems (fig. 28). It has small, rather thick leaves. Bluish-white flowers are borne at the end of the stems. It usually occurs in circular mats 1 foot or more in diameter. Under lawn conditions, it appears as shown in figure 29, A.

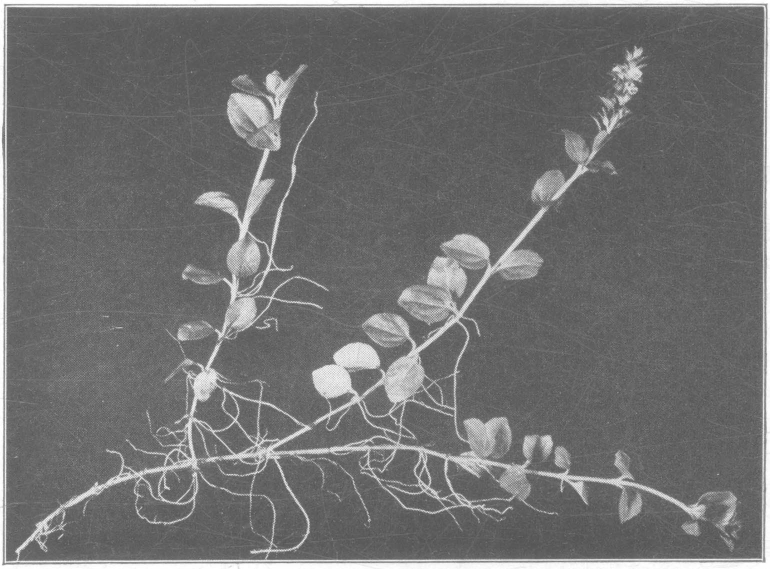


Fig. 28.—Speedwell, habit of growth

CONTROL

Thyme-leaved speedwell was eliminated with sodium chlorate used in the same strength and in the same way as directed for ground ivy. Since speedwell usually occurs in small patches, it is neither necessary nor advisable to spray the entire lawn area. In spraying miscellaneous spots, just enough solution should be applied to moisten the leaves. If the mat of speedwell is not too dense, reseeding after treatment may not be necessary. An area treated November 6, 1928, and not reseeded, appeared August 21, 1929, as shown in figure 29, B.

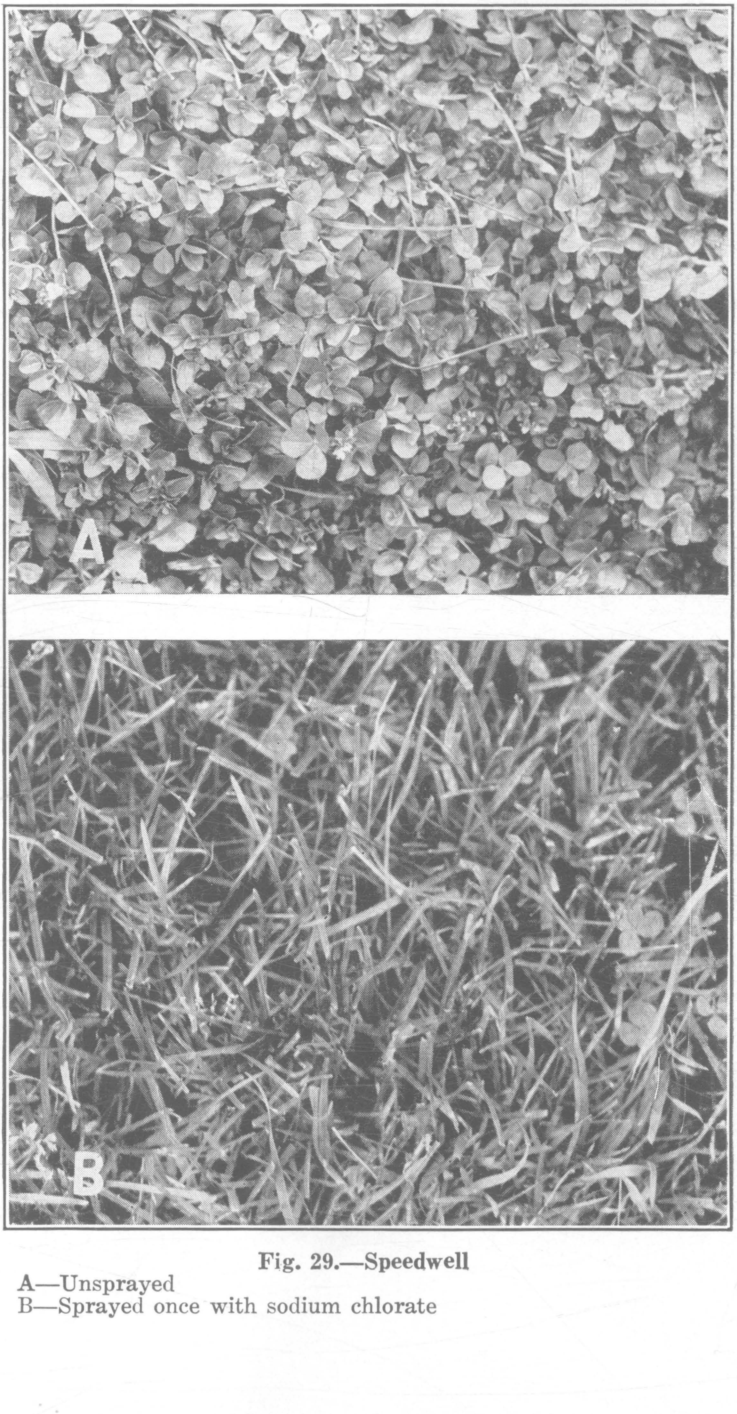


Fig. 29.—Speedwell

A—Unsprayed
B—Sprayed once with sodium chlorate

COMMON CHICKWEED, WINTER-WEED (*ALSINE MEDIA* L.)

CHARACTERISTICS

Common chickweed is a winter annual reproducing by seed and by rooting at the nodes of the much-branched and creeping stems (fig. 30, A). The small smooth, pointed leaves and the very small white flowers make it easy to recognize. Under lawn conditions, it appears as shown in figure 30, B.

CONTROL

Treatments made in 1929 and later showed that this weed can be killed with sodium chlorate. If the weed is intermixed with grass, repeated spraying with a weak solution, one-half per cent, is preferable. Where the saving of grass is not a factor, the chickweed can be killed with one application of a more concentrated solution, 6 per cent. With the stronger solution, reseeding will be necessary.

According to Smock (11) common chickweed can be killed with Cyanamid applied at the rate of 12 to 15 pounds per 1,000 square feet. In this quantity, Cyanamid will kill some grass, and reseeding will probably be necessary. Cyanamid is best adapted for use in places devoid of grass, as, for example, in vegetable gardens, a place where this chickweed frequently occurs in great abundance.

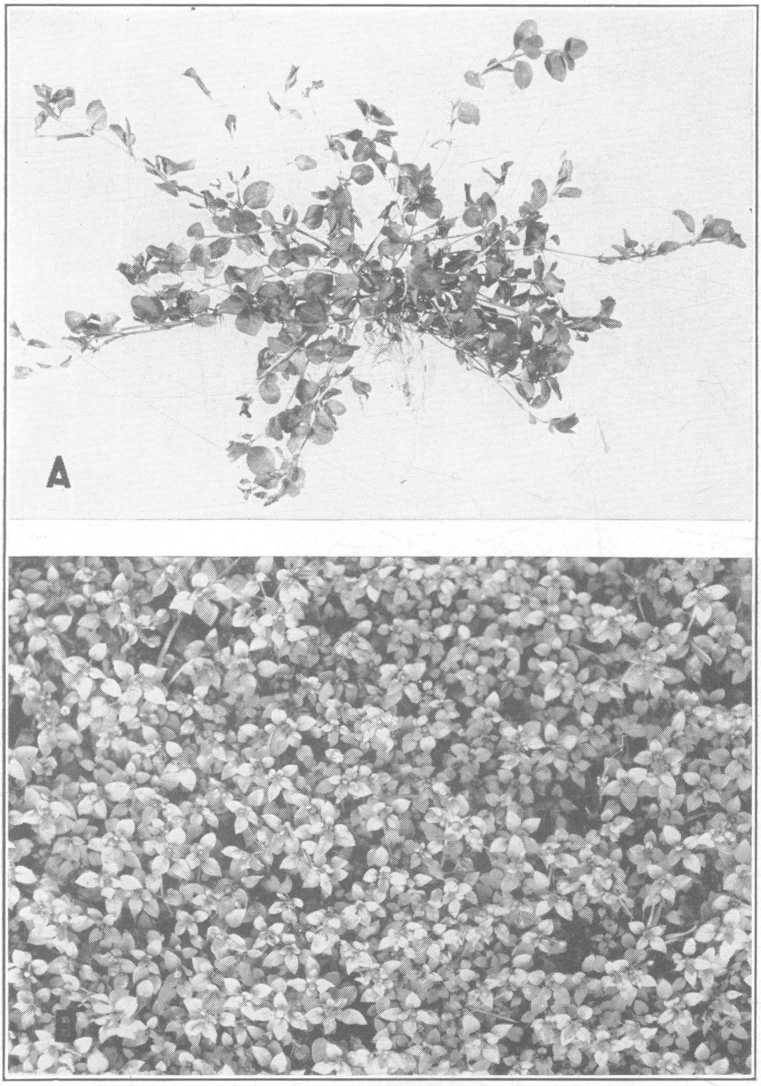


Fig. 30.—Common chickweed

A—Habit of growth
B—Under close mowing and in bloom

MOUSE-EAR CHICKWEED (*CERASTIUM VULGATUM* L.)

CHARACTERISTICS

Mouse-ear chickweed is a perennial reproducing by seed and by rooting at the lower nodes of the stem (fig. 31, A). On the partially prostrate stems are borne small, hairy, dark green leaves and terminal clusters of white flowers. Where the stand is dense and under close mowing, it appears as shown in figure 31, B. It usually occurs in small patches which are quite as easily detected in winter as in summer because the leaves retain their characteristic green color throughout the cold weather.

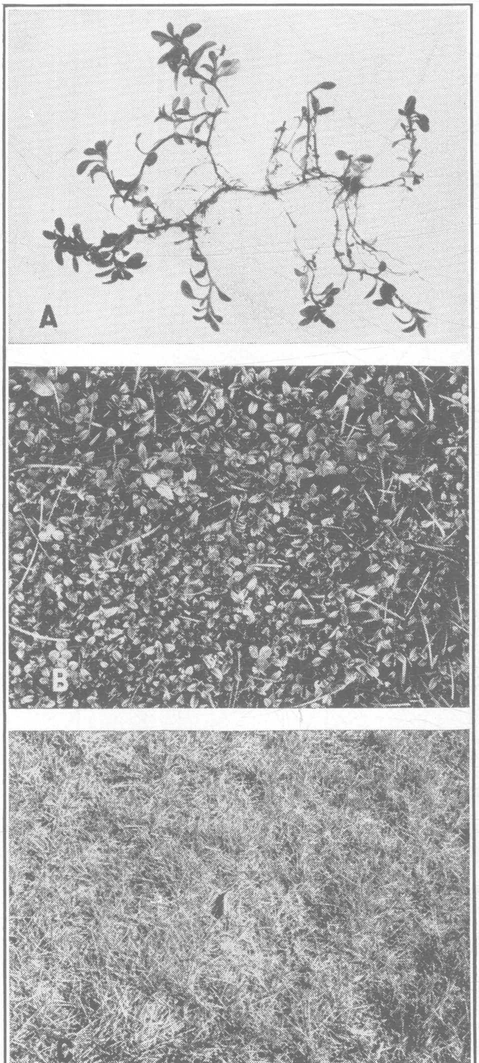


Fig. 31.—Mouse-ear chickweed

A—Prostrate habit of growth
B—Dense mat under close mowing
C—After dusting with ammonium sulfate

CONTROL

SODIUM CHLORATE

Mouse-ear chickweed usually occurs in more or less isolated patches and ordinarily, therefore, does not call for treatment in a wholesale way. It yields readily to sodium chlorate. On the campus of the Ohio Experiment Station in the winter of 1929-1930, it was killed by wetting thoroughly at intervals of about 3 weeks with a one-half per cent solution four times or with a 6 per cent solution once. The use of the weaker solution is preferable where there is enough grass to try to save.

AMMONIUM SULFATE

Mouse-ear chickweed was also eliminated by dusting with ammonium sulfate. As much was put on as would cling to the leaves, preferably when they were wet either with dew or rain. A badly infested area dusted January 15, 1930, appeared without reseeding on April 5, 1930, as shown in figure 31, C.

HEAL-ALL, SELF-HEAL (*PRUNELLA VULGARIS* L.)

CHARACTERISTICS

Heal-all is a perennial reproducing by seed and by short stolons. Naturally, the stems are erect and grow about 1 foot high, bearing a dense head of violet-blue flowers at the terminal end. In lawns, however, the stems are prostrate and often root at the nodes (fig. 32, A). Under frequent mowing, it forms a dense mat in which the flower heads are almost obliterated by the rather large, egg-shaped leaves (fig. 32, B).

CONTROL

SODIUM CHLORATE

Heal-all yields readily to sodium chlorate. Repeated trials on the Experiment Station Campus have shown that it can be killed in the fall or winter with about three applications of a one-half per cent solution or one application of a 2 per cent solution.

IRON SULFATE

Heal-all can be killed also by spraying with iron sulfate (copperas), 1½ pounds per gallon of water. One thorough wetting with such a solution in September completely killed several patches on the Experiment Station Campus.

MILK PURSLANE, SPOTTED SPURGE (*CHAMAESYCE MACULATA* (L.) SMALL)

CHARACTERISTICS

Milk purslane is a summer annual reproducing by seed. The much-branched, prostrate stems radiate in all directions (fig. 33, A). If the stems are broken, a milky, poisonous juice exudes. On the upper surface of the oblong leaves, brownish-red spots frequently occur. Milk purslane is often found in barren places, as along the edge or in the cracks of brick or cement walks. In lawns it is not always particularly harmful, although where the stand of desirable grasses is thin, it may temporarily gain almost complete possession (fig. 33, B).

CONTROL

Milk purslane yields readily to sodium chlorate. Tests showed that a 2 or 3 per cent solution of sodium chlorate is required to kill with one application after the plants have become well developed. In the seedling stage, a 1 per cent solution will kill. Less injury will result to the desirable grasses from the use of a one-half per cent solution used repeatedly at intervals of 2 or 3 weeks if necessary.

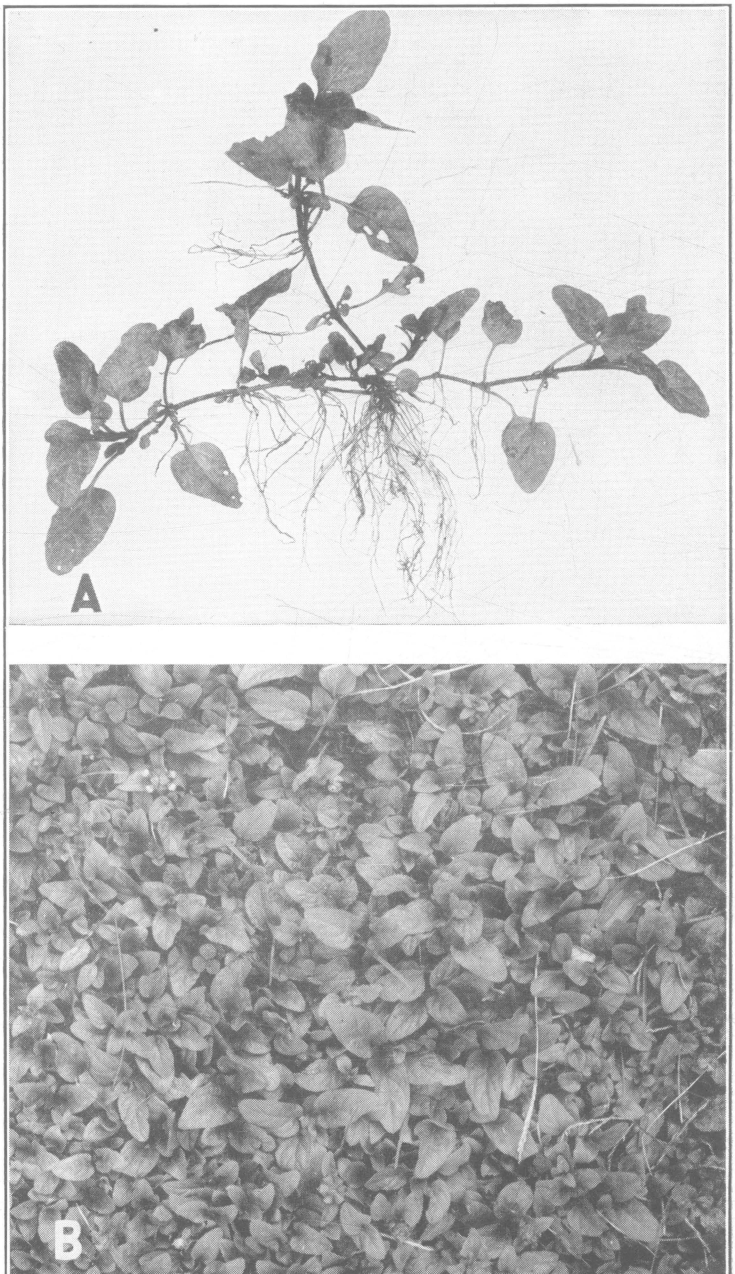


Fig. 32.—Heal-all

A—Habit of growth
B—Dense mat under close mowing

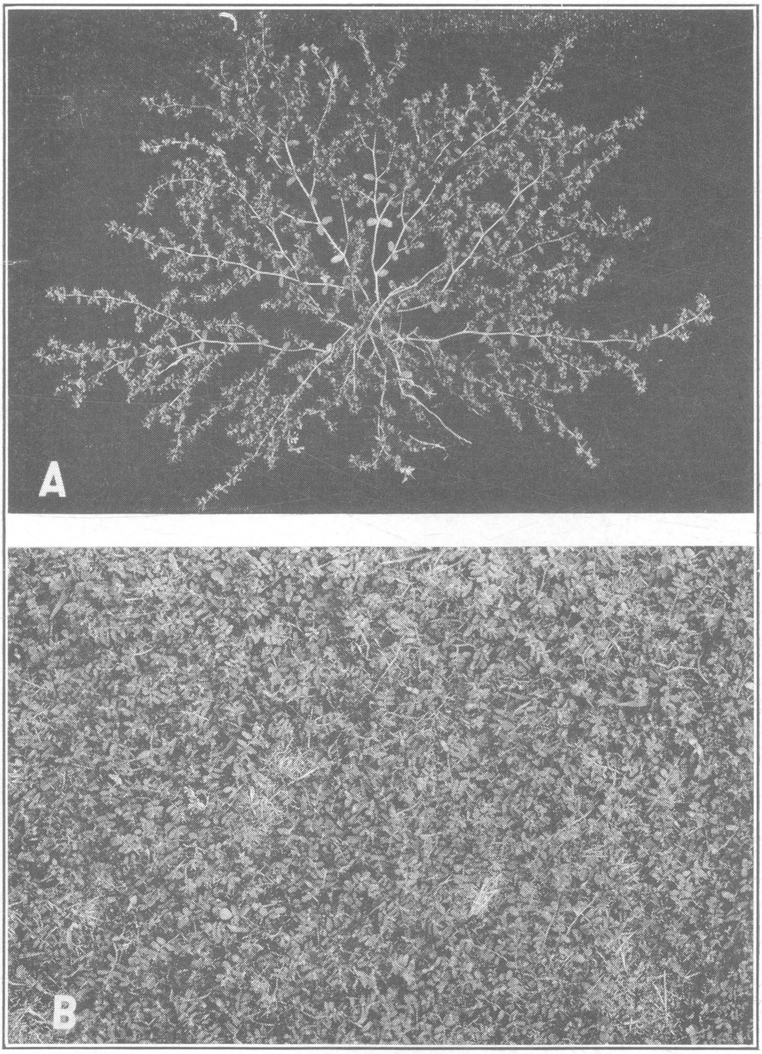


Fig. 33.—Milk purslane

A—Branching habit of growth
B—Dense stand that may develop under close mowing

CREEPING BUTTERCUP (*RANUNCULUS REPENS* L.)

CHARACTERISTICS

Creeping buttercup is a perennial propagating by seed and by runners. On the hairy stems are borne three-parted, hairy, dark green leaves, often splotched with white, and showy yellow flowers (fig. 34, A). The flowers usually appear in June. Under close mowing, creeping buttercup may occupy the ground to the exclusion of almost everything else (fig. 34, B).

CONTROL

The authors know of no treatment that will kill creeping buttercup without injuring the grass so severely that reseeding will be necessary. Creeping buttercup can be killed, however, with either sodium chlorate or ammonium thiocyanate liquor.

SODIUM CHLORATE

Creeping buttercup was sprayed January 26, 1931, with sodium chlorate in ½, 1, 2, 3, 4, 5, 6, 7, and 8 per cent solutions. Two-thirds of the area treated with each strength was given a second spraying February 16. One-third was given a third spraying March 26. The creeping buttercup was killed with two applications of solutions of 5 per cent and stronger and with three applications of the 3 per cent solution. Reseeding was necessary. Inasmuch as repeated applications of either a 3 or 5 per cent solution injured the grass, it is probable that a stronger solution, 10 to 12 per cent, would be preferable, for it would probably kill with one application.

AMMONIUM THIOCYANATE

In another test, creeping buttercup was sprayed January 19, 1934, with ammonium thiocyanate liquor, 2, 4, and 8 gallons per 1,000 square feet. The heaviest application was required to kill. Reseeding was necessary.

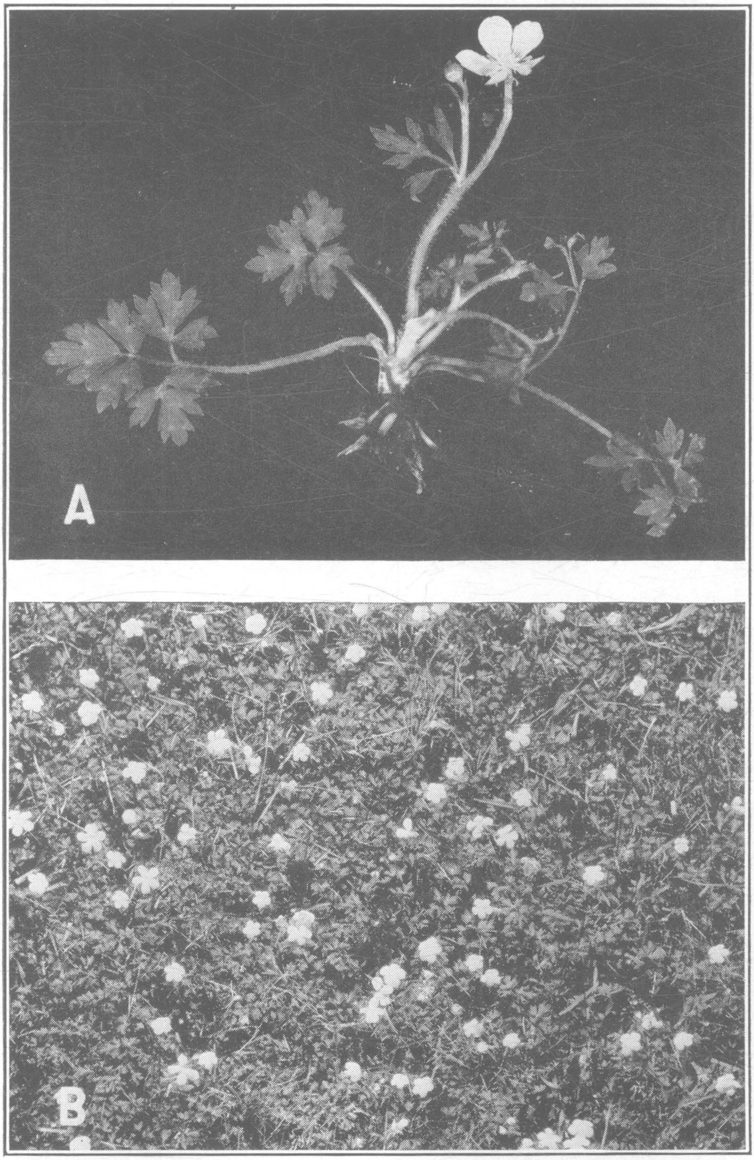


Fig. 34.—Creeping buttercup

A—A single plant
B—Under close mowing and in bloom

MONEYWORT, CREEPING LOOSESTRIFE, YELLOW MYRTLE (*LYSIMACHIA NUMMULARIA* L.)

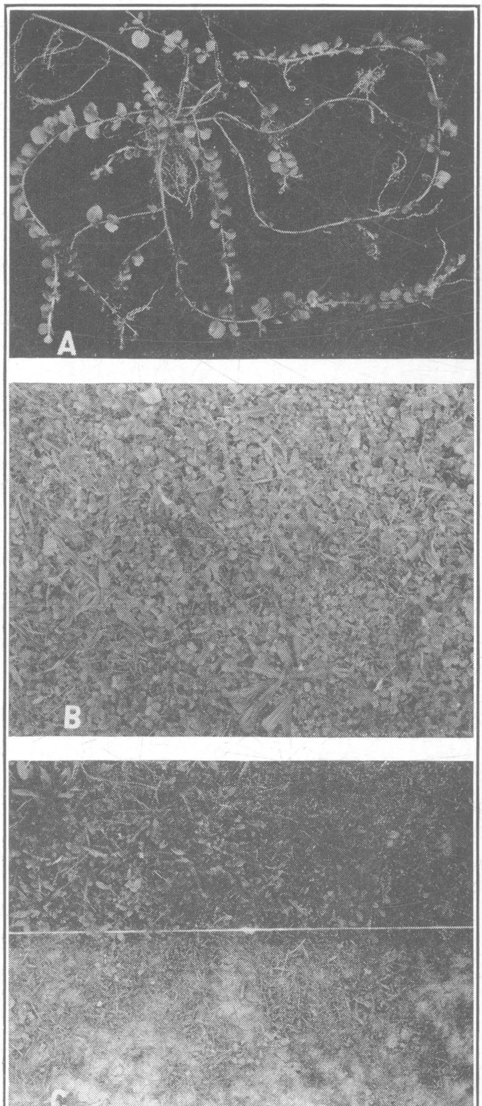


Fig. 35.—Moneywort

A—Habit of growth
B—Under close mowing (buckhorn interspersed)
C—Sprayed with a 4 per cent solution of sodium chlorate. One application did not kill (top); two did (bottom).

CHARACTERISTICS

Moneywort is a perennial reproducing by seed and by runners, chiefly by runners (fig. 35, A). On the smooth, creeping stems are borne roundish, yellowish-green leaves and showy yellow flowers. It occurs on lawns and often in public cemeteries. Under close mowing, it appears as shown in figure 35, B.

CONTROL

No satisfactory control for this plant has been found. It yields, however, with considerable injury to the grass, to either sodium chlorate or sodium chloride (common salt).

SODIUM CHLORATE

Moneywort was sprayed January 4, 1932, with sodium chlorate in ½, 1, 2, 3, 4, 5, 6, and 7 per cent solutions. On two-thirds of the area treated with each solution, a second application was made about 3 weeks later, and on one-third, a third application was made about 6 weeks later. One application of the 7 per cent solution was not satisfactory, but practically all the moneywort was killed with three applications of the 3 per cent solution and with two applications of the 4 per cent solution (fig. 35, C). As repeated applications of either strength killed the grass, a stronger solution, 8 to 10 per cent, might well be used. The stronger solution would probably kill with one application.

COMMON TABLE SALT

An area of moneywort was treated August 31, 1933, with a solution of sodium chloride, common table salt, used at the rate of 2½ pounds per gallon of water and applied at the rate of 10 gallons per 1,000 square feet. This solution killed much of the moneywort, but the control was not complete. The salt was applied by means of a sprinkling can. This method, of course, did not give as complete and thorough coverage as could be obtained by means of a pressure sprayer.

A second plot of moneywort was treated with common salt August 30, 1937. The same strength of solution was used as in the previous test, but it was applied by means of a power sprayer. The control in the second test was almost complete. The grass was somewhat, but not severely, injured.

YARROW, MILFOIL (*ACHILLEA MILLEFOLIUM* L.)

CHARACTERISTICS

Yarrow is an ill-smelling perennial reproducing by seed and by rootstocks (fig. 36, A). In pastures, the erect stems attain a height of 2 to 4 feet. On these stems are borne fernlike leaves and terminal clusters of white or pinkish flowers. In lawns, no seed is formed and yarrow spreads only by enlargement of individual plants. Under close mowing, it appears as shown in figure 36, B. Its presence usually indicates low fertility.

CONTROL

Yarrow can be eliminated through liberal and systematic fertilization without serious permanent injury to the grass. Various materials can be used.

AMMONIUM PHOSPHATE

In an area badly infested with yarrow, six plots, each 5 by 10 feet, were treated with ammonium phosphate (Ammo-Phos A) at the rate of 6 pounds per 1,000 square feet in the summer of 1932. The first treatment was made May 28. Subsequent applications were made each month through October. On each date the number of plots treated was diminished by one. At the close of the season, therefore, the series showed the effect of one, two, three, four, five, and six applications. To facilitate even distribution, the fertilizer was mixed with 10 times its weight of sand. The yarrow was not completely eliminated on any of the plots by this procedure. The following spring, however, it was perceptible that some had disappeared from the plots that had received the greater number of treatments.

In 1933, the test was repeated on the same series of plots. The first application was made May 18. When the top-dressings for the second year were finished, much of the yarrow had disappeared on the plot that had received five doses each year, and practically all had disappeared from the one that had received six a year. Reseeding was not necessary. Dawson and Evans (1) also found ammonium phosphate effective in eliminating yarrow.

NITROPHOSKA

An adjoining series of plots was treated in the same manner with Nitrophoska at the rate of 10 pounds per 1,000 square feet. At the end of the second year, the plot receiving six applications per year was nearly free from yarrow, but the fertilizer had killed the grass in small spots. In subsequent years, however, the grass spread and re-established itself without reseeding. Probably the injury to the desirable grasses would have been negligible, as with the use of ammonium phosphate, if the quantity of Nitrophoska applied had been somewhat less.

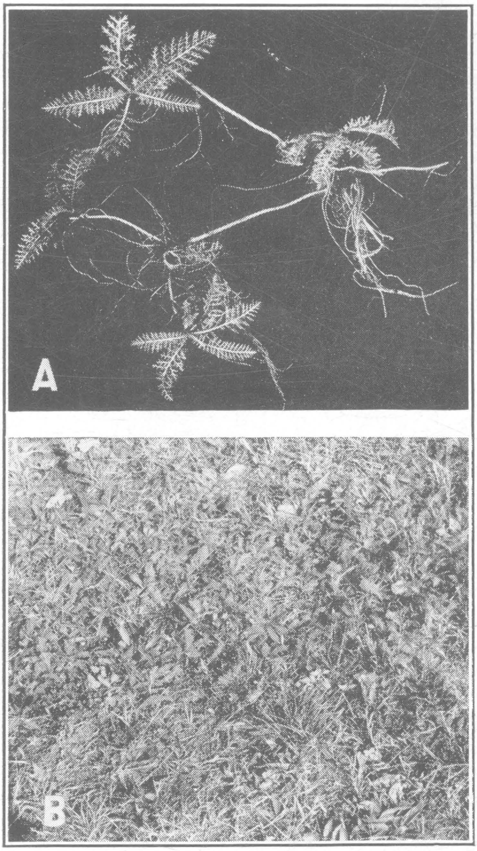


Fig. 36.—Yarrow

A—Habit of growth
B—Under close mowing

AMMONIUM SULFATE AND IRON SULFATE COMBINED

A third series of plots adjoining the other two was treated with a mixture of ammonium sulfate and calcined iron sulfate (copperas), 3.5 pounds of ammonium sulfate and 1.75 pounds of iron sulfate per 1,000 square feet. The two were applied in mixture with 10 times their combined weight of sand. Some yarrow was eliminated from the plot receiving six top-dressings, but the results were much less satisfactory than were those obtained in the other two tests, particularly the one in which ammonium phosphate was used.

SODIUM CHLORATE

Yarrow yields to sodium chlorate, but a strong solution is required, and its use on lawns is not practicable. A series of plots of old and well-established yarrow in a pasture was sprayed with 4, 8, 12, and 16 per cent solutions of sodium chlorate November 3, 1932. The chlorate was applied at the rate of 10 gallons per 1,000 square feet. The 16 per cent solution killed most, but not all, the yarrow.

AMMONIUM THIOCYANATE

In the same pasture, a series of plots was sprayed December 29, 1932, with ammonium thiocyanate liquor used at the rates of 2, 4, 6, 8, and 10 gallons per 1,000 square feet. A little yarrow remained even with the heaviest application.

SHEEP SORREL, FIELD SORREL, HORSE SORREL, SOURWEED, SOUR GRASS (*RUMEX ACETOSELLA* L.)

CHARACTERISTICS

Sheep sorrel is a perennial reproducing by seed, also by rootstocks, as shown in figure 37, A. The arrowhead-shaped light green leaves are characterized by a sour taste. Under close mowing, sorrel may appear as shown in figure 37, B.

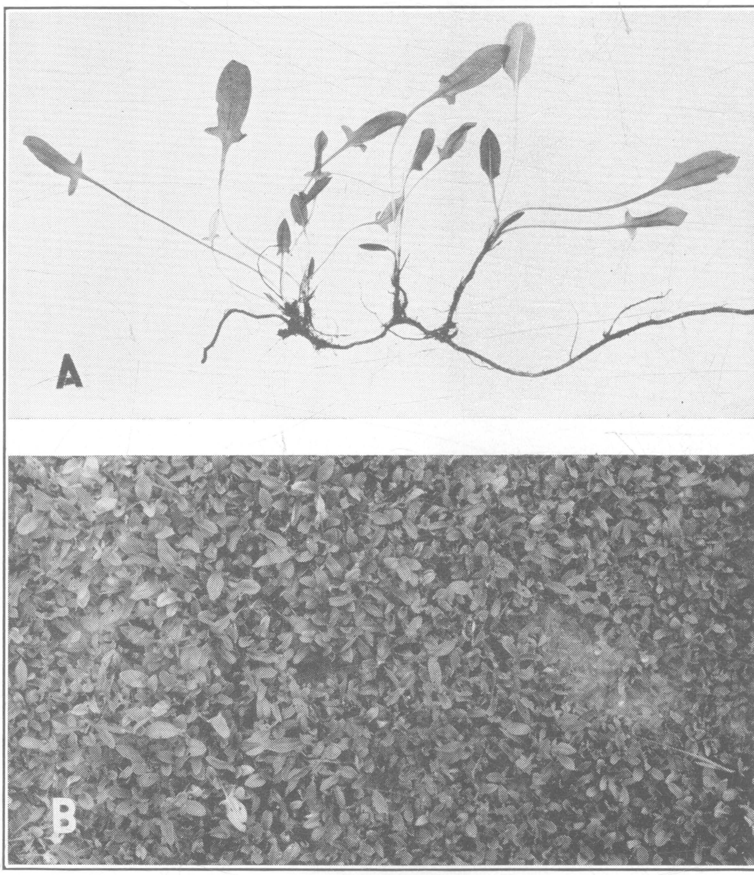


Fig. 37.—Sorrel

A—Habit of growth
B—Under close mowing

CONTROL

No satisfactory procedure for eliminating sorrel without severe injury to the grass is known. Partial control, however, can be obtained through the use of certain chemicals.

IRON SULFATE

A terrace badly infested with sorrel was sprayed with iron sulfate, 1½ pounds per gallon of water, applied at the rate of 3½ gallons per 1,000 square feet. Six monthly sprayings were made in the late fall and winter of 1930-1931; the first was applied in September and the last in February. As a result, the growth of the plants was severely checked and the stand was appreciably reduced, but not all the plants were killed. The grass also was somewhat injured. The area was fertilized with 10-6-4 on March 19 and reseeded March 31, 1931. A good stand of grass was secured. The thinning of the sorrel was not permanent, for it gradually became prominent again. By 1937, 6 years after treatment, the improvement had become negligible.

SODIUM CHLORATE

Somewhat better results were obtained from the use of sodium chlorate. On another portion of the same terrace, duplicate plots were sprayed with a three-fourths per cent solution of sodium chlorate. On a second pair a 1½ per cent solution was used. Both strengths were applied at the rate of 10 gallons per 1,000 square feet. Each of the six monthly sprayings was made on the same dates as were those of iron sulfate. The weaker solution was altogether inadequate. The stronger solution, however, reduced the stand materially. These areas too were fertilized and reseeded. The stronger treatment resulted in appreciable improvement, but after 6 years the sorrel had become prominent again.

In a portion of a meadow badly infested with sorrel, two areas were sprayed in the summer of 1932; a third was sprayed in December of the same year. In each of these three tests, sodium chlorate was used in various strengths. As a result, it was found that sorrel can be killed with one application of this agent if it is used in a concentration of at least 6 per cent and at the rate of 10 gallons per 1,000 square feet.

KAINIT

In a lawn a portion of which was badly infested with sorrel, two plots were treated with Kainit at the rate of 75 pounds per 1,000 square feet. On one, the total quantity of material was divided into five equal parts and applied at the rate of 15 pounds per 1,000 square feet in five monthly applications, beginning November 4, 1932, and ending March 15, 1933. On the other plot, all was put on in one application, November 4. This material reduced the sorrel but little at the time, and 4 years later, 1937, there was no evidence of any reduction.

AMMONIUM THIOCYANATE

An area badly infested with sorrel was sprayed December 29, 1932, with ammonium thiocyanate liquor used at the rates of 2, 4, 6, 8, and 10 gallons per 1,000 square feet. Even the strongest solution was not sufficient to kill completely in one application.

DOORWEED, KNOTGRASS, MATGRASS, PROSTRATE KNOTWEED (*POLYGONUM AVICULARE* L.)

CHARACTERISTICS

Doorweed is an annual reproducing by seed. The pale green, usually prostrate stems branch in all directions from a deeply penetrating white taplike root, as shown in figure 38. The joints in the stems are surrounded by a scalelike tissue. The leaves are bluish green. The flowers are greenish white with pinkish margins and develop from June to October. The seedlings appear as early as March. The dying plants become brown in November. Doorweed is common on much-trampled ground, such as yards, athletic fields, pathways, drives, and waste places.

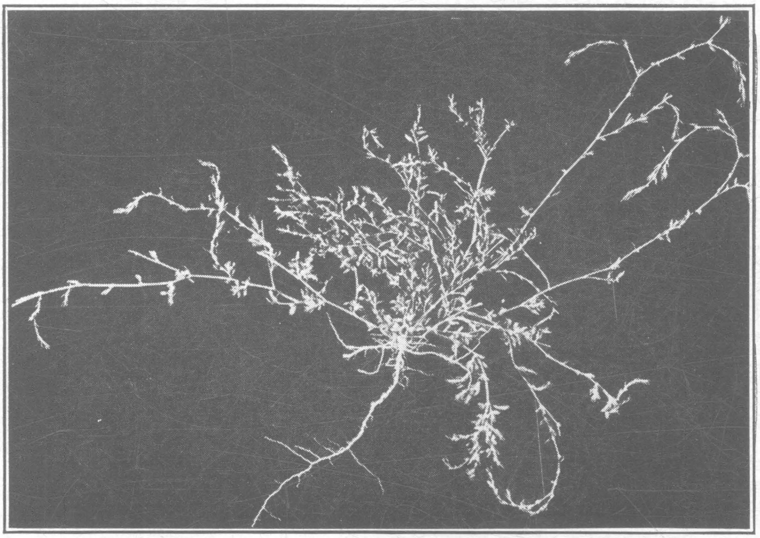


Fig. 38.—Doorweed, habit of growth

CONTROL

Doorweed is difficult to eliminate without injury to the grass. It yields, however, to chemical treatment.

SODIUM CHLORATE

A lane in which thrifty doorweed was well established was sprayed July 6, 1932, with 4, 8, and 12 per cent solutions of sodium chlorate, each applied at the rate of 10 gallons per 1,000 square feet. The 12 per cent solution was required to kill completely (fig. 39).

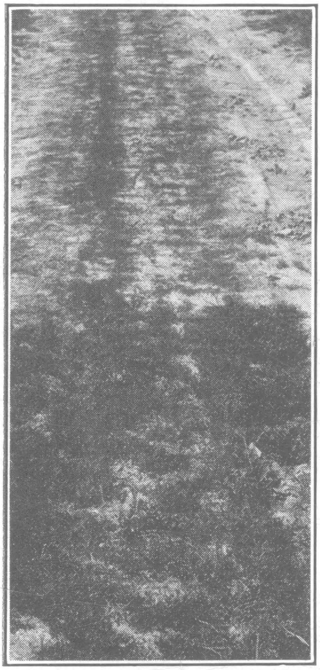


Fig. 39.—Doorweed, unsprayed in foreground; sprayed with 12 per cent sodium chlorate, in background. All sprayed plants were killed.

AMMONIUM THIOCYANATE

In a second lane, three plots of rank doorweed were sprayed August 17, 1933, with ammonium thiocyanate liquor used at the rates of 8, 12, and 16 gallons per 1,000 square feet. The 12- and 16-gallon rates but not the 8-gallon rate killed all the plants.

CYANAMID

Where doorweed is intermixed with grass, neither sodium chlorate nor ammonium thiocyanate is a satisfactory killing agent, because if used in sufficient strength to kill the weed, both will kill the grass. Much, however, can be accomplished by treating the contaminated area in early winter, about December, with Cyanamid at the rate of 80 pounds per 1,000 square feet. If applied after the tops are more or less decayed and the seeds have fallen to the ground, Cyanamid will kill most of the weed seeds. In this quantity, it will injure the remaining grass, and reseeding will usually be necessary.

QUACK-GRASS, COUCH-GRASS (*AGROPYRON REPENS* L.)

CHARACTERISTICS

Quack-grass is a perennial reproducing by seed and by rootstocks. Under close mowing it does not produce seeds but spreads from the rootstocks alone. The rootstocks are yellow in color, jointed, much branched, and tend to form a dense mat. The flat, narrow, slate-green leaves are rough above but smooth underneath.

CONTROL

Because of its extensive root system, quack-grass is difficult to kill, but its destruction can be accomplished in various ways. The severity of the treatment required will necessitate reseeding.

SODIUM CHLORATE

Quack-grass can be killed by one spraying with sodium chlorate if an 18 per cent solution is applied at the rate of 10 gallons per 1,000 square feet. If evenly distributed, the chlorate can be applied as a dry salt for rains to dissolve and carry into the soil. If the treatment is made in the late fall, in November, then the chlorate will be sufficiently leached out of the soil by the following March that it will not interfere with reseeding.

SHADING

If quack-grass is located close to shrubbery or under trees, where the use of a strong solution of chlorate is inadvisable, the lawnowner can resort to shading. For this purpose, anything that will exclude light can be used. Tar paper, cardboard, garden mulch paper, or other similar materials are satisfactory.

CYANAMID

Quack-grass can also be killed with Cyanamid. A series of plots was treated October 31, 1933, at the rates of 40, 80, 120, and 160 pounds per 1,000 square feet. A second series was treated November 29, 1935. In these tests, the dust form was used. In both trials the quack-grass was killed, but with the heaviest application only. If applied in the fall, Cyanamid will probably not interfere seriously with reseeding early the following spring, sometime in March. Some difficulty was experienced with early reseeding in the dry spring of 1934.

ORCHARD GRASS (*DACTYLIS GLOMERATA* L.)

CHARACTERISTICS

Orchard grass is a tussock-forming perennial without creeping rootstocks. It reproduces by seed. This grass is relatively deep rooted and is, therefore, difficult to eliminate. It is undesirable in lawns because it grows in tufts and because its leaves do not blend well with those of the fine turf grasses. They are stiff, wide, rough, and ashy green in color. Their relatively rapid rate of growth is a further undesirable quality of this grass in a lawn.

CONTROL

Orchard grass can be killed by top-dressing with Cyanamid. In a series of plots treated with Cyanamid (dust) at the rates of 80, 100, 120, 140, and 160 pounds per 1,000 square feet October 30, 1933, the 120-pound rate was required to kill the grass. In a second test, made November 25, 1935, with the same rates, the heaviest one, 160 pounds per 1,000 square feet, was required to kill. From these two tests, therefore, it would appear unsafe to use less than 150 pounds per 1,000 square feet. After these treatments, reseeding was, of course, necessary.

WHITE CLOVER (*TRIFOLIUM REPENS* L.)

CHARACTERISTICS

White clover is a perennial reproducing by seed and by creeping stems. It is so universally distributed and generally recognized that a description is unnecessary. In some seasons it is much more conspicuous than in others. The periodicity in appearance undoubtedly results from the interaction of many factors, including abundance of moisture. Heavy rainfall tends to induce luxuriant vegetative growth on which a profusion of bloom may develop the following year if rainfall is light. This periodicity has been observed occasionally on the Experiment Station Campus. In 1925, a mass of bloom appeared, as shown in figure 40. In the preceding year, the rainfall had been above normal in May, June, July, and September. Again in 1936, a profusion of white clover bloom appeared. In the preceding year, the rainfall had been above normal in May, June, July, and August. It was 9.34 and 9.53 inches in July and August, respectively, a total of 18.87 inches, an increase over the 45-year average at Wooster of 152 per cent.

Positive proof of a relationship between vegetative growth of white clover and rainfall was afforded by the Station's lawn watering test. The plots in this test were seeded with Kentucky bluegrass in the spring of 1932. In 1934, all the plots except two were watered artificially from May through October according to a fixed plan. The quantity added varied from the equivalent of 10 to 19 inches of rainfall. By 1935, white clover had become conspicuous on all the artificially watered plots, but there was a sprinkling only in evidence on the unwatered areas. The contrast, as it appeared June 12, 1935, was very marked (fig. 41).

CONTROL

If for any reason the presence of white clover in turf is objectionable, it can be eliminated by top-dressing with ammonium sulfate or some other nitrogenous fertilizer. In the 1935 dandelion test, the white clover, as well as the dandelions, was eliminated by all the fertilizers used.

Fig. 40.—White clover on the Station Campus, 1925

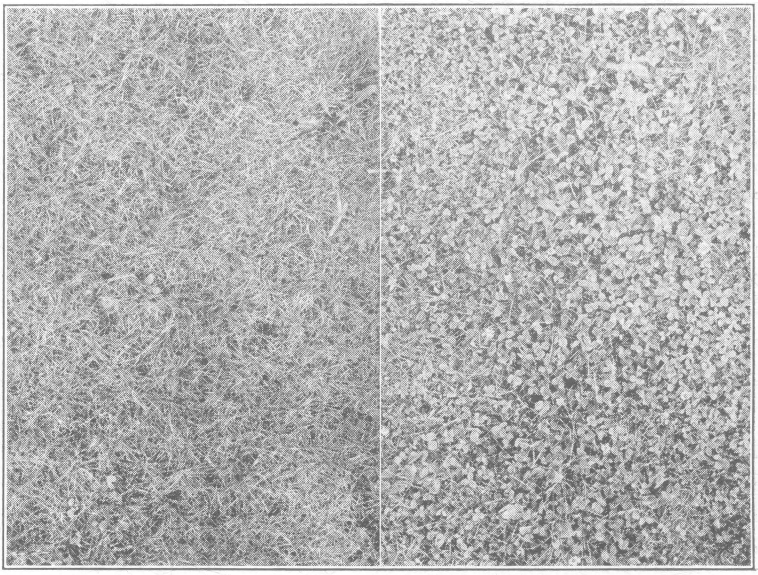


Fig. 41.—Left—Rainfall only. Right—Rainfall plus artificial watering

MOSS

CHARACTERISTICS

The mosses constitute a large assemblage of the lower groups of plants. There are 13,000 or more. This multitude of forms represents a wide range in adaptation to environmental conditions from bogs to highly xerophytic conditions. In situations favorable for the growth of more luxuriant vegetation, mosses rarely gain a foothold. They do not appear in lawns unless conditions are unfavorable for the growth of grass.

The presence of moss may or may not indicate a sour soil. Whether it does or not depends on the kind. According to Ikenberry (5), 46 forms are more or less generally distributed in Ohio. The distribution of only a few of these appears to be associated with the reaction of the soil; some are restricted largely to acid, others to alkaline, conditions. Most of the species, however, are found growing over a considerable range in soil reaction.

CONTROL

In most places, the appearance of moss in lawns indicates either a poor soil, too much water, too much shade, or some combination of these adverse factors. The real remedy, of course, is to remove the cause. If the soil is poor, fertilization and possibly liming will be helpful.

Most lawns are adequately drained, but occasionally a part of some may become too wet, as, for example, where water from eaves is discharged on the surface rather than through a conduit underground. In such places, Pohlin or other similar mosses may develop during wet periods. With the coming of hot, dry weather, the moss may die, leaving a brownish or black crust. Adequate drainage will usually terminate the appearance of the moss.

Certain types of moss flourish in partial or dense shade, particularly in spring and fall, when rainfall is usually abundant. If the removal of the cause of the shade is impractical or undesirable, a little pruning of the trees will often help.

At least some forms of moss commonly found in lawns, like *Mnium cuspidatum*, can be eliminated with various chemicals. Several areas, 5 by 5 feet, covered with this moss and located on the Station Campus under trees (elms, oaks, maples) were treated May 18, 1932. All the chemicals were applied at two rates. The kinds of material, the rates of application, and the results are shown in table 12.

TABLE 12.—Elimination of moss

Materials	Pounds per 1,000 square feet		Approximate percentage of coverage			
			1 year after treatment		4 years after treatment	
	Light	Heavy	Light	Heavy	Light	Heavy
Sodium nitrate	5.00	10.00	95	25	100	100
Ammonium sulfate	5.00	10.00	95	25	100	100
Ammonium sulfate Iron sulfate (calcined) Sand	3.50 1.75 16.00	7.00 3.50 32.00	95	25	100	100
Nitrophoska	5.00	10.00	40	0	100	100
Kainit	35.00	70.00	0	0	70	60

Sodium nitrate and ammonium sulfate applied at the rate of 5 pounds per 1,000 square feet had little effect, but where the quantity was doubled, about three-fourths of the moss was killed. The substitution of iron sulfate (calcined) for a part of the ammonium sulfate did not increase the effectiveness. Nitrophoska was more effective than either sodium nitrate or ammonium sulfate. Kainit in the relatively heavy quantities used eliminated all the moss.

After 4 years, however, the ground was again covered with moss in all places except where the Kainit had been used. These results show that moss can be removed by the use of certain chemicals. If, however, the cause for its first appearance is not corrected, the moss will gradually reappear and soon become re-established.

WEEDS IN WASTE PLACES ADJACENT TO LAWNS

In addition to the weeds already considered, there are many which frequent waste places adjacent to lawns, especially around farm premises. The conditions under which such weeds occur usually permit drastic treatment, for ordinarily there is little, if any, grass that it is important to save. Control measures for the more conspicuous of these follow.

ROUND-LEAVED MALLOW, LOW MALLOW, CHEESES (*MALVA ROTUNDIFOLIA* L.)

CHARACTERISTICS

Mallow is an annual or biennial reproducing by seed. On the procumbent stems spreading from the long tapering roots are borne rounded or kidney-shaped leaves and rather small white or pinkish flowers, (fig. 42). Mallow is usually found on much-trodden ground. Occasionally it gains a foothold in newly seeded lawns, but under close mowing it does not persist long.

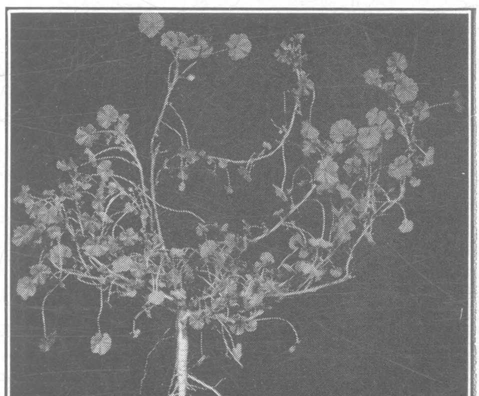


Fig. 42.—Mallow

CONTROL

SODIUM CHLORATE

Mallow yields to treatment with sodium chlorate. Vigorous plants along a drive were killed with one spraying of sodium chlorate October 1, 1930. A 12 per cent solution was used at the rate of 10 gallons per 1,000 square feet. Mature plants in a pasture were killed November 28, 1933, with the same strength and quantity of solution.

AMMONIUM THIOCYANATE

In a second test, the sodium chlorate was used in different strengths and in comparison with ammonium thiocyanate liquor. A 6 per cent solution of sodium chlorate was more effective than was ammonium thiocyanate liquor applied at the rate of 8 gallons per 1,000 square feet.

TALL NETTLE, STINGING NETTLE (*URTICA GRACILIS* AIT.)

CHARACTERISTICS

Nettle is a perennial reproducing by seed, also by rootstocks, as shown in figure 43. On the stems, which may be 3 to 6 feet tall, are borne egg-shaped, coarsely toothed leaves, bristly stinging hairs, and clusters of greenish flowers.

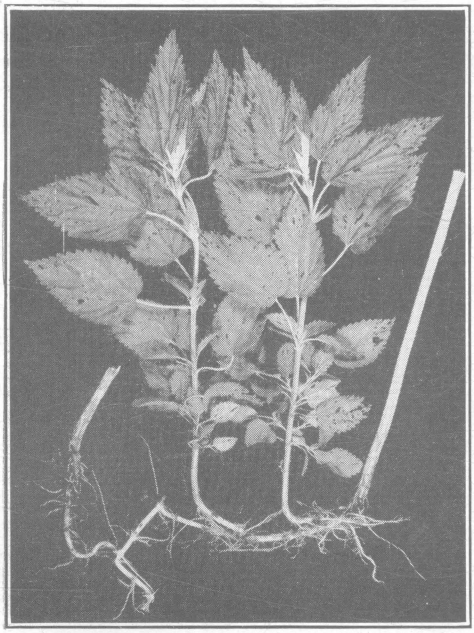


Fig. 43.—Stinging nettle

CONTROL

Nettle can be killed by spraying with sodium chlorate. June 17, 1932, vigorous plants which had been mowed and had their tops removed were sprayed with sodium chlorate. Two strengths of solution, 8 and 12 per cent, were used. Both were applied at the rate of 10 gallons per 1,000 square feet. The stronger one only killed all the plants with one application.

In a second test, made June 8, 1933, on thrifty plants 5 feet and taller located on the border of an old stone quarry where the soil was gravelly, a stronger solution, 18 per cent, was required to kill with one application. Probably the need for the stronger solution was due to the difference in type of soil; the 1932 test had been located on a clay loam.

WILD CARROT, BIRD'S NEST (*DAUCUS CAROTA* L.)

CHARACTERISTICS

Wild carrot is a biennial reproducing by seed. On the bristly haired stems, 2 to 4 feet tall, are borne much-divided leaves resembling parsley and umbels of white to pinkish flowers which turn in, forming a cavity resembling a bird's nest.

CONTROL

Wild carrot can be killed with sodium chlorate. A series of plots containing plants which had been mowed and had their tops removed was sprayed August 22, 1933. A second series, after receiving the same preparation, was sprayed August 27, 1934. In both years the plants were in full bloom at the time of treatment. Both tests showed that in order to kill the plants with one application, it was necessary to use a strong solution, 18 per cent, applied at the rate of 10 gallons per 1,000 square feet.

POKEWEED, POKEBERRY, SCOKE, GARGET (*PHYTOLACCA DECANDRA* L.)

CHARACTERISTICS

Pokeweed is a perennial reproducing by seed. It has a large, white, fleshy root and reddish stems 2 to 8 feet tall on which are borne whitish flowers and grapelike clusters of juicy purple berries (fig. 44).

Fig. 44.—Pokeweed

CONTROL

SODIUM CHLORATE

Pokeweed can be killed with sodium chlorate, but a strong solution is required. A series of plots was sprayed July 21, 1932, when the plants were in bloom, with three strengths of solution, 12, 24, and 36 per cent, and each solution was applied at the rate of 10 gallons per 1,000 square feet. Before the plants were sprayed, their tops were removed. An examination of the plots the following year, June 22, 1933, showed that all the plants were dead except those on the plot receiving the weakest solution.

A second series of plots was sprayed June 27, 1933, with solutions of 12, 16, 20. and 24 per cent. The details of application were the same as in 1932. In this test, the strength of solution required to kill was 24 per cent, the same as in the preceding year.

SPUDDING

Pokeweed yields to spudding if the root is cut off below the crown. In a woods, 20 plants were cut off at ground level and 20 at least 1 inch below the surface on June 10, 1936. The location of these roots was marked. An examination made in October of the same year showed that all the plants cut off at the ground level had survived and sent up new stalks. None of those cut off 1 inch below the surface had sprouted, but the stub root remained. A second examination, made in October 1937, revealed that 18 of the 20 plants cut off at the ground level the preceding year had again developed an upright stem; two had not. The roots of the latter had disappeared entirely. No trace of the root of any of the 20 cut off below the surface was found.

YELLOW DOCK, SOUR DOCK, CURLED DOCK (*RUMEX CRISPUS* L.)

CHARACTERISTICS

Yellow dock is a perennial reproducing by seed. In the first year, this plant develops a taproot with a rosette of leaves. In later years, the stems may attain a height of 3 or more feet, and on these are borne characteristically narrow, curled leaves and, in season, whorls of greenish flowers and reddish-brown fruits. The young leaves are often used as "greens." Under close mowing, yellow dock appears as shown in figure 45.

Fig. 45.—Yellow dock under close mowing

CONTROL

Yellow dock does not yield easily, but it can be killed by spraying with a strong solution of sodium chlorate. In tests including strengths of 12, 18, 24, and 36 per cent applied at the rate of 10 gallons per 1,000 square feet, it was found that an 18 to 24 per cent solution was required to kill in one application.

Yellow dock yields to spudding. Ten plants were cut off 1 inch or more below the surface of the ground May 30, 1935. An examination made in the fall of 1935 and a second one in July 1936 revealed that none of them had survived. The year-old stubs remained, but no shoots had developed. Twelve plants were similarly cut off June 5, 1936. None of these showed any evidence of sprouting by July 2, 1936, when the test was destroyed by highway construction.

BURDOCK (*ARCTIUM MINUS* SCHK.)

CHARACTERISTICS

Burdock is said to be a biennial reproducing by seed. In the first year, the burdock sends out leaves only. In the seeding year, it produces an upright stem, 3 to 6 feet tall, on which are borne rounded leaves and purplish flowers. It becomes prominent and very conspicuous in late June and July. Seeds mature in late August or early September. The burdock has a deep taproot, as shown in figure 46.

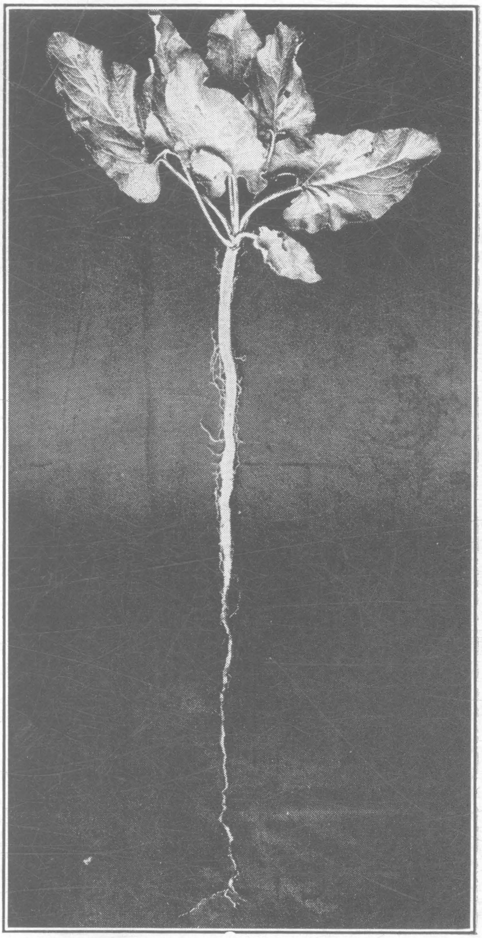


Fig. 46.—One-year-old burdock with taproot 2½ feet long

Photographed October 14, 1933

CONTROL

MOWING

If mowing is resorted to as a method of control, it is frequently done in July soon after the plants become showy. That is a poor time, for often new shoots spring from the stub, as shown in figure 47. On these secondary stems, sometimes short and inconspicuous, viable seeds may develop and drop to the ground, defeating the objective of extermination.

In order to determine the approximate time at which burdock can be cut off with assurance that the balance of the season is too short for the development of viable seeds on secondary shoots, groups of plants were cut off at three stages of development. The approximate dates of cutting were July 15, August 1, and August 15, and the test was made in each of 4 years, 1934, 1935, 1936, and 1937. The plants were cut off 3 to 5 inches above ground level. Later, the number of plants producing burs, the number producing burs containing seeds, and the viability of the seeds produced were determined. The results obtained were as shown in table 13.

TABLE 13.—When to cut burdock

	1934			1935			1936			1937		
	July 15	August 1	August 15	July 15	August 1	August 15	July 15	August 1	August 15	July 15	August 1	August 15
Number of plants cut off	9	4	12	20	20	20	20*	20	20	20	20	20
Number of plants which sprouted and produced burs	5	4	12	0	0	1	3	12	14	10	1	2
Number of plants bearing viable seed	5	4	0	0	0	1	2	11	6	10	0	1
Range in percentage of germination of seed per plant	58-100	51-79	.....	.....	.....	.....	62-97	3-86	1-9	21-75	.....	.....

*Seventeen destroyed by sheep.

Viable seeds were produced on the plants cut off July 15, in 3 of the 4 years. The number produced on plants cut off August 15 was negligible. In 1935, practically all the roots rotted because of their location on low ground and excessive summer rains (9.34 inches in July and 9.53 inches in August). From these results, it would appear that it is unsafe to cut off burdock plants until well into August if seed production on the second growth is to be avoided.

If burdock plants are allowed to reach an advanced stage, the safe procedure is to permit them to go to maturity or near maturity and then either mow or pull them out by the roots, collect them in a pile, and burn them. In this way the seed will be destroyed. At maturity, the organic food reserves are largely exhausted. As a consequence, the deep taproot is much withered and the entire plant can often be pulled out easily.

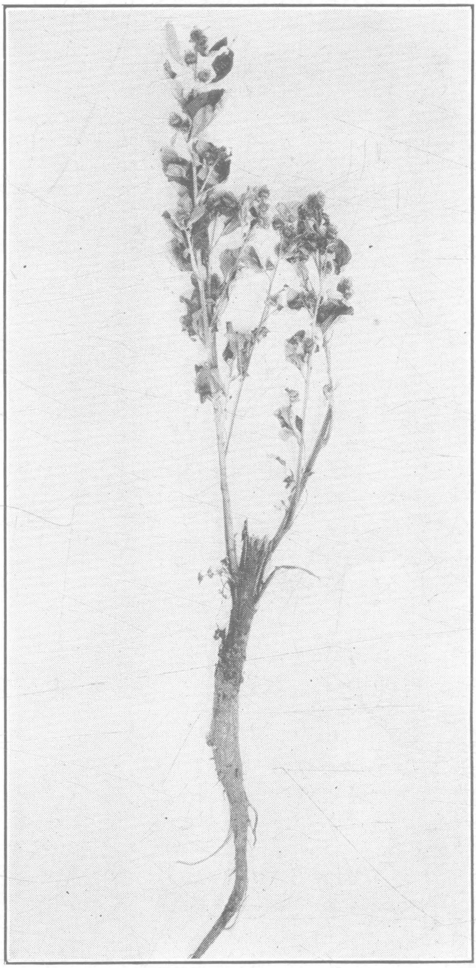


Fig. 47.—Second-growth burdock stems developed between July 16 and September 2, 1929.

Viable seeds were produced.

SPUDDING

Cutting at the blooming stage is ineffectual if it is done at the surface of the ground. Burdock must be cut at least 1½ to 2 inches below the surface. Twenty plants were cut off 1½ to 2 inches below the ground in May, June, July, August, September, and October, 1935. At the time of cutting, the location of the roots of each was marked. At the close of the season of 1936, an examination of these roots was made. Not one was found from which a new shoot had developed. In this test were included in June and again in July, 20 additional plants in the rosette stage. The results on these first-year plants were the same as those on the second-year ones.

SODIUM CHLORATE

If for any reason spudding the individual plants is impractical, they can be killed by spraying with sodium chlorate. One patch sprayed in July 1933 and another in 1934, with solutions of different strength, showed that burdock could be killed in one application with an 18 per cent solution applied at the rate of 10 gallons per 1,000 square feet. Little, if any, difference in effect was observable as a result of not cutting off the tops or of cutting and removing them before spraying.

POISON IVY, POISON OAK (*TOXICODENDRON RADICANS* (L.) KTZ.)

CHARACTERISTICS

Poison ivy is a perennial reproducing by seed and rootstocks. It usually grows as a woody vine, sometimes prostrate and trailing in waste places, but more often clinging by aerial roots to fences, walls, and tree trunks. Occasionally the lianas are shrubby. Contact with poison ivy gives most people a painful skin eruption called "ivy poisoning." The plant should be avoided except by those immune to its action. Poison ivy is characterized by three leaflets on each leaf stalk and is, therefore, easily distinguished from the harmless and beautiful Virginia creeper, which has five or more leaflets. Poison ivy bears clusters of greenish-white flowers in late spring and early summer and gray or cream-colored fruit, which remains until winter.

CONTROL

Poison ivy yields readily to sodium chlorate. The chlorate can be applied as a spray of 12 per cent solution or as the dry salt used at the rate of 10 pounds per 1,000 square feet. More may be required in some conditions, as where the ivy is rooted at the base of trees. Four such places were treated with the dry salt November 21, 1932, at the rates of 5, 10, 15, and 20 pounds per 1,000 square feet. In this test, only the heaviest rate killed the ivy. The entire surface under the branches of the trees was not treated; the areas covered ranged from 50 to 65 square feet. Eight years later (1940) no injury was observed to the mature soft maple trees on which the ivy had been climbing.

Evidence is available that at least some other trees are not easily injured by this chemical. Sodium chlorate was applied at the rate of 10 pounds per 1,000 square feet under a dogwood, a maple, a red cedar, and an oak December 8, 1930. The trees were of good size, having diameters of approximately 7, 11, 10, and 14 inches, respectively. Under each tree, the area over which the chlorate was spread coincided with that covered by the spread of the branches. No injury to these trees had been detected by December 1940.

KILLING WEED SEEDS

CHLOROPICRIN

For use around shrubbery and as a top-dressing for turf, particularly the bent grasses, materials like compost or woods soil are useful, but they are often so badly contaminated with weed seeds that their use results in the introduction of many weeds. Where facilities are available to supply heat, the weed seeds can be killed either through the use of steam or by electricity. Both are expensive. Moreover, steaming may damage the physical condition of the soil. Drenching with chemicals like formaldehyde or hydrogen cyanide is expensive and involves a long time of waiting before the soil is in shape to handle. A highly effective material which does not involve a long waiting time and whose cost is not prohibitive is desirable. Chloropicrin (tear gas) appears to be such an agent.

Chloropicrin, trichloronitromethane, CCl_3NO_2, is, in the pure state, a colorless, oily, noninflammable liquid, practically insoluble in water but soluble in alcohol and many other organic solvents. Although it causes eyes to water, coughing, and other disagreeable effects, it is not dangerous to use, because it is impossible to resist voluntarily dosages that are permanently harmful. Relief from temporary discomfort is speedy in fresh air. No harmful effect results from accidental spilling on the skin or on clothing.

For a quarter of a century or more, the properties of chloropicrin have been studied with a view to its possible use in agriculture. Many uses have been and are being found. Recently, it has been suggested that chloropicrin may have some value in the destruction of weed seeds. Accordingly, it was used as a killing agent in the summer of 1938 on a group of seeds representing the weeds most commonly found in turf areas and some in addition. The group was comprised of the 31 kinds listed in table 14.

One hundred seeds of each kind were mixed with about a teaspoonful of white sterilized sand. The mixture was wrapped in thick muslin, buried in sterilized soil in a 4-gallon glazed jar, watered liberally in order that the moisture content of the seed might simulate that of seed in soil, and treated with chloropicrin at the rate of 20 ounces per cubic yard. The chloropicrin was sealed in with glue-coated kraft paper, allowed to stand 4 days, removed to flats of sterilized soil, and then placed in the greenhouse under conditions favorable for germination. An additional set, not treated with chloropicrin, was placed in sterilized soil at the same time to serve as a check.

The seeds were placed in flats July 27, 1938, and 5 weeks later, August 31, the seedlings were counted. None of the seeds treated with chloropicrin germinated. Of the untreated or check seeds, four kinds, ragweed, milkweed, lamb's quarters, and knotweed, failed to grow. With the possible exception of knotweed, this failure to grow was due to the sprouting of these seeds while buried.

In the summer of 1939, the test was repeated. The details were the same as in 1938. In this second test, five lots of seed, yarrow, knotweed, dandelion, soapwort, and paspalum, failed to grow. Of the rest, chloropicrin killed all except 2 per cent of the ragweed and 1 per cent of the old-witch-grass.

TABLE 14.—Kinds of weed seeds on which chloropicrin was used

Common name	Scientific name
Yarrow	*Achillea millefolium* L.
Common chickweed	*Alsine media* L.
Pigweed	*Amaranthus retroflexus* L.
Ragweed	*Ambrosia artemisiifolia* L.
Mayweed	*Anthemis cotula* L.
Burdock	*Arctium minus* Schk.
Milkweed	*Asclepias syriaca* L.
Shepherd's-purse	*Bursa bursa-pastoris* (L.) Britt.
Mouse-ear chickweed	*Cerastium vulgatum* L.
Foxtail	*Chaetochloa glauca* (L.) Scrib.
Lamb's-quarters	*Chenopodium album* L.
Wild carrot	*Daucus carota* L.
Goose grass	*Eleusine indica* (L.) Gaert.
Milk purslane	*Chamaesyce maculata* (L.) Small
Pepper grass	*Lepidium virginicum* L.
Nimblewill	*Muhlenbergia schreberi* Gmel.
Old-witch-grass	*Panicum capillare* L.
Paspalum	*Paspalum laeve* Mx.
Buckhorn	*Plantago lanceolata* L.
Broad-leaved plantain	*Plantago major* L.
Annual bluegrass	*Poa annua* L.
Doorweed	*Polygonum aviculare* L.
Knotweed	*Polygonum erectum* L.
Purslane	*Portulaca oleracea* L.
Heal-all	*Prunella vulgaris* L.
Sorrel	*Rumex acetosella* L.
Yellow dock	*Rumex crispus* L.
Soapwort	*Saponaria officinalis* L.
Small crabgrass	*Syntherisma ischaemum* (Schreb.) Nash
Large crabgrass	*Syntherisma sanguinale* (L.) Dulac
Dandelion	*Leontodon taraxacum* L.

In the fall of 1938, two boxes, each 25 by 38 by 15 inches, were filled with Wooster silt loam soil. Imbedded in each box was a 2-inch layer of soil contaminated with a mixture of weed seeds, the 31 kinds already mentioned. This weed-contaminated soil was placed between two layers of fine wire fly netting in order to facilitate the removal of the weed seeds to flats for germination. This layer was placed 4 inches from the bottom of the box, and then the box was filled to the top with soil. The two uncovered boxes were allowed to stand outdoors all winter.

On May 24, the contents of one box were treated with chloropicrin at the rate of 15 ounces[11] per cubic yard. The treatment was accomplished by making 24 holes 6 inches apart to a depth of 12 inches. Into each hole were placed 1.5 cubic centimeters of chloropicrin at the bottom and 1.5 cubic centimeters at a depth of 6 inches. The two quantities were separated by the filling in of soil between applications. The holes were made by the insertion of a pointed rod one-fourth inch in diameter, and the chloropicrin was added through a piece of glass tubing attached to a burette by a piece of rubber tubing. The box was then covered with boards, and all cracks were sealed with glue-coated kraft paper. The boxes were then allowed to stand 5 days.

[11]Avoirdupois.